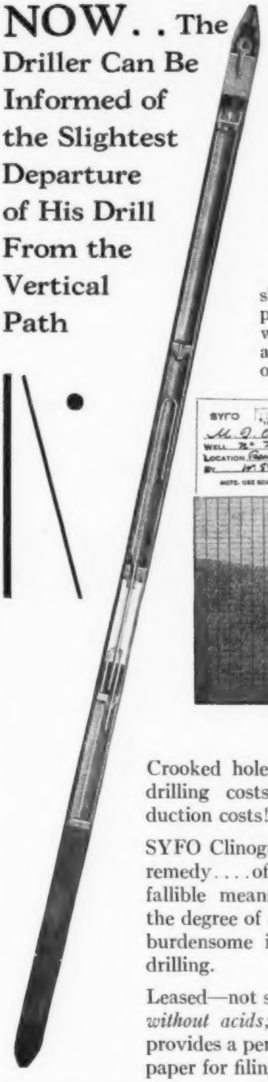
Volume 15 JULY 1931 Number 7

BULLETIN
of the
American Association *of* Petroleum Geologists

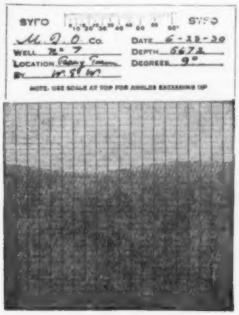
CONTENTS

NOW . . The Driller Can Be Informed of the Slightest Departure of His Drill From the Vertical Path



Sectional view of a SYFO Clinograph. Let down on a wire line or can be dropped into the hole by the "Go-Devil" method.

A SYFO recording sheet giving complete information which may be filed as a permanent record.



Crooked holes mean increased drilling costs. . . . greater production costs!

SYFO Clinograph provides the remedy. . . . offering an easy, infallible means of determining the degree of deviation without burdensome interruption to drilling.

Leased—not sold. . . . it *operates without acids;* is accurate and provides a permanent record on paper for filing.

Write for catalog and quotations, stating conditions and number of wells.

Also makers of the SURWEL Clinograph.

SPERRY-SUN WELL SURVEYING CO.
Main Office - 1608 Walnut St., PHILADELPHIA, PA.
Dallas, Texas: 1504 First National Bank Bldg.
Los Angeles, Calif.: 415 Petroleum Securities Bldg.
Tulsa, Oklahoma: 402 Petroleum Bldg.
Houston, Texas: 1417 Esperson Bldg.
Calgary, Alberta, Can.: Room 1, Central Block

The SYFO *Clinograph*

RECENT McGRAW-HILL BOOKS for Petroleum Geologists

Emmons' GEOLOGY OF PETROLEUM
New Second Edition

By William Harvey Emmons, Professor and Head of Department of Geology and Mineralogy, University of Minnesota; Director Minnesota Geological Survey. 736 pages, 6 x 9, 435 illustrations. **$6.00**

A complete, up-to-date reference work for the petroleum geologist, covering the geologic characteristics of oil fields, large and small, throughout the world. The book contains many new illustrations, index maps and cross sections.

Lahee's FIELD GEOLOGY
New Third Edition

By Frederic H. Lahee, Chief Geologist of the Sun Oil Company. 789 pages, 538 illustrations, pocket size, flexible **$5.00**

A thorough revision of this well-known manual of field geology, covering recent extensive advances in methods of geological exploration and mapping, particularly those that have been developed to meet the needs of the petroleum industry.

Ver Wiebe's OIL FIELDS IN THE UNITED STATES

By Walter A. Ver Wiebe, Professor of Geology, University of Wichita. 629 pages, 6 x 9, 230 illustrations. **$6.00**

A complete and systematic presentation of the fundamental facts of oil accumulation in all fields of the United States.

Examine these books for 10 days FREE
Send This Coupon

McGRAW-HILL FREE EXAMINATION COUPON

McGraw-Hill Book Company, Inc.,
370 Seventh Ave., New York City.

Send me the books checked below, postpaid, for ten days' free examination. I agree to pay for or return them within ten days of receipt.

Emmons—*Geology of Petroleum,* $6.00
Lahee—*Field Geology,* $5.00
Ver Wiebe—*Oil Fields in the United States,* $6.00

Signed. . . . .
Address. . . . .
City and State. . . . .
Firm. . . . .
Position P.G.7-1-31

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on or about the 15th of each month. Editorial and publication office, 505 Tulsa Building, Tulsa, Oklahoma, Post Office Box 1852. Cable address, AAPGEOL.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 1 Fleet Lane, Ludgate Circus, London, E. C. 4.

German agent: Max Weg, Königstrasse 3, Leipzig, Germany.

CLAIMS FOR NON-RECEIPT of preceding numbers of the BULLETIN must be sent to the business manager within three months of the date of publication in order to be filled gratis.

BACK NUMBERS of the BULLETIN, as available, can be ordered from Association headquarters. Cloth-bound Vol. 2 (1918), $4.00; Vol. 3 (1919), $5.00; Vol. 5 (1921), $12.00; Vols. 11 (1927), 12 (1928), 13 (1929), 14 (1930), each $17.00. Other volumes, many separate numbers, and a few nearly complete sets are available. Descriptive price list sent on request. Special prices to members and associates. Discounts to libraries. Detailed *10-Volume Index* (1917-1926), $1.00. *Theory of Continental Drift* (1928), $3.50. *Structure of Typical American Oil Fields*, Vol. I (1929), $5.00; Vol. II (1929), $6.00; each volume $4.00 to members and associates; after January 1, 1932, Vol. II will be $7.00 ($5.00 to members and associates).

THE BULLETIN furnishes thirty-five free reprints of major papers. Additional reprints and covers for all or part, are furnished at cost. ORDERS FOR REPRINTS should accompany corrected galley proof.

Association Headquarters—505 Tulsa Building, East Fifth Street at Cincinnati Avenue, Tulsa, Oklahoma.

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

J. P. D. HULL, *Business Manager*
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.
BOX 1852
TULSA, OKLAHOMA

Entered as second-class matter at the Post Office of Tulsa, Okla., under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

MID-WEST PRINTING CO., TULSA, OKLA., U. S. A.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

OFFICERS FOR THE YEAR ENDING MARCH, 1932

LOVIC P. GARRETT, *President*
Houston, Texas

SIDNEY POWERS, *Past-President*
Tulsa, Oklahoma

L. COURTNEY DECIUS, *First Vice-President*
San Francisco, California

FRANK RINKER CLARK, *Second Vice-President in Charge of Finances*, Tulsa, Oklahoma

FREDERIC H. LAHEE, *Third Vice-President in Charge of Editorial Work*, Dallas, Texas

DISTRICT REPRESENTATIVES

(Representatives' terms expire immediately after annual meetings of the years shown in parentheses.)

Amarillo:
Victor Cotner (1932), Amarillo, Tex.
Appalachian:
Leon J. Pepperberg (1933), Columbus, Ohio
Canada:
Theodore A. Link (1933), Calgary, Canada
Capital:
H. D. Miser (1932), Washington, D. C.
Dallas:
Willis Storm (1932), Dallas, Tex.
East Oklahoma:
John M. Nisbet, (1932), Bartlesville, Okla.
W. R. Hamilton (1933), Tulsa, Okla
R. S. Knappen (1933), Tulsa, Okla.
Fort Worth:
H. B. Fuqua (1933), Fort Worth, Tex.
Great Lakes:
Theron Wasson (1933), Chicago, Ill.
Houston:
John F. Weinzierl (1933), Houston, Tex.
Mexico:
S. A. Grogan (1933), Tampico, Mexico
New Mexico:
R. K. DeFord (1933), Roswell, New Mexico
New York:
H. J. Wasson (1933), New York, N. Y.
Pacific Coast:
Harry R. Johnson (1933), Los Angeles, Calif.
C. R. McCollom (1932) Los Angeles, Calif.
R. D. Reed (1933), Los Angeles, Calif.
Rocky Mountains:
R. Clare Coffin (1933), Denver, Colo.
San Antonio:
Ed. W. Owen (1933), San Antonio, Tex.
Shreveport:
S. C. Stathers (1933), Shreveport, La.
South America:
C. A. Baird (1933), Maracaibo, Venezuela, S. A.
Southern Permian Basin:
Joseph E. Morero (1933), San Angelo, Tex.
West Oklahoma:
A. H. Richards (1933), Oklahoma City, Okla.
Wichita:
L. W. Kesler (1933), Wichita, Kan.
Wichita Falls:
J. P. Bowen (1932), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Division of Paleontology and Mineralogy:
R. C. Moore (1932), Lawrence, Kan.
Gayle Scott (1932), Fort Worth, Tex.

PACIFIC SECTION

(Chartered, March, 1925)

M. G. EDWARDS, *President*, 433 Higgins Building, Los Angeles, California
L. N. WATERFALL, *Secretary-Treasurer*, 1114 Union Oil Building, Los Angeles, California

Membership is restricted to members of the A.A.P.G. in good standing, residing in the Pacific Coast states. Dues of $2.00 per year are payable to the secretary-treasurer of the Pacific Coast Section. Members of the A.A.P.G. transferring to the Pacific Coast are cordially invited to become affiliated with the local section, and to communicate their change of address promptly to the secretary-treasurer of the Pacific Section.

SAN ANTONIO SECTION

(Chartered, April, 1929)

HERSCHEL H. COOPER, *President*, 1642 Milam Building, San Antonio, Texas
J. D. HEDLEY, *Secretary-Treasurer*, 1014 Milam Building, San Antonio, Texas

Membership is limited to persons who are eligible to membership in The American Association of Petroleum Geologists. Annual dues: $2.50. Annual meeting: the last Friday in February.

MARACAIBO SECTION

(Chartered, April, 1930)

WILLIAM H. SPICE, JR., *President*, Lago Petroleum Corporation, Maracaibo, Venezuela
CHESTER A. BAIRD, *Secretary-Treasurer*, Venezuela Gulf Oil Company, Maracaibo, Venezuela

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Affiliated, March, 1928; chartered, technical division, April, 1930)

CHARLES E. DECKER, *President*, Norman, Oklahoma
GAYLE SCOTT, *Secretary-Treasurer*, Texas Christian University, Fort Worth, Texas

The Society issues a quarterly, the *Journal of Paleontology*, Raymond C. Moore, editor, University of Kansas, Lawrence, Kansas: subscription, $6.00. Society dues (including subscription to *Journal*), $6.00. A remission of $2.00 is allowed on dues of members who are also members or associate members of the Association. Therefore, members or associate members of the Association in good standing who are engaged in stratigraphic studies as applied to petroleum geology are eligible to membership in the society, and may receive the *Journal of Paleontology* for $4.00 in addition to their Association dues. Membership application forms and back numbers of the *Journal* may be obtained from Association Headquarters, Box 1852, Tulsa, Oklahoma.

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Volume 15 **JULY 1931** **Number 7**

CONTENTS

Articles Scheduled for Publication in the August *Bulletin*

General Geology of Northeast Mexico

By J. L. TATUM

Venezuelan Oil-Field Waters

By J. E. SMITH

Function of Carrier Beds in Long-Distance Migration of Oil

By JOHN L. RICH

Deep Sand Development in Tioga County, Pennsylvania

By JACK GADDESS

Richland Gas Field, Richland Parish, Louisiana

By DUGALD GORDON

Exceptional Association of Oil and Water in Producing Zones at Refugio, Texas

By R. G. MAXWELL

Volume 15 Number 7

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JULY 1931

MICROSCOPIC SUBSURFACE WORK IN OIL FIELDS OF UNITED STATES[1]

R. D. REED[2]
Los Angeles, California

ABSTRACT

On the basis of information furnished by subsurface workers in different districts, an attempt is made in this paper to describe the present status of the application of the microscope to the solution of subsurface problems in the oil fields of the United States. Corresponding with the geology of the different areas, the development of microscopic work has assumed widely different forms, but the degree of success attained seems to be uniformly high. Contributions to regional geology made by the new methods are already great, and the promise for the future is bright.

INTRODUCTORY STATEMENT

Since the first wells were drilled for oil and gas, more or less intensive studies have been made of the materials penetrated in them. Fifteen years ago most such studies were made at second hand. The driller defined the rock types penetrated, many without even a casual inspection of them, and the geologist studied the driller's record. Unpromising as the procedure sounds, it worked fairly well, especially in areas underlain by regular beds of well consolidated rock with fairly simple structure. In less favored regions many of the results were entirely undependable. In the Los Angeles basin, for example, they were almost useless except in developed fields where correlations could be based on reports of oil sands or showings.

[1]Presented before the Association at the San Antonio meeting, March 20, 1931. Manuscript received, February 15, 1931.

[2]Chief geologist, The Texas Company, 929 South Broadway.

Attempts to supplement the information furnished by drillers' logs were made by enterprising or inquisitive individuals at many times and places. Udden made microscopic examinations (36)[1] of deep well samples in Illinois 20 years ago. Others made similar attempts elsewhere. Ten years ago such work was becoming sufficiently common so that its promise was generally recognized. During the last 10 years it has become all but universal in the more important oil districts. Laboratories for sample study are maintained by most large and many small oil companies, stratigraphic societies exist in several cities, and a national association of subsurface stratigraphers has been in existence since 1926.

In order to secure a general view of the present status of microscopic subsurface work, the writer recently sent out lists of questions to several well known stratigraphic workers in different parts of the country. Detailed answers, many of them supplemented by discussions of interesting data not specifically requested, were received from all of them. The present paper thus owes its existence to the kindness and interest of these collaborators. In alphabetical order their names and company affiliations are as follows.

Paul L. Applin, Cosden Oil Company, Fort Worth, Texas
Dorothy Ogden Carsey, Humble Oil and Refining Company, McCamey, Texas
Lon D. Cartwright, Superior Oil Company, San Angelo, Texas
R. Clare Coffin and W. A. Waldschmidt, The Midwest Refining Company, Denver, Colorado
Fanny Carter Edson, Shell Petroleum Corporation, Tulsa, Oklahoma
Alva Christine Ellisor, Humble Oil and Refining Company, Houston, Texas
M. A. Hanna, Gulf Production Company, Houston, Texas
G. Dallas Hanna and C. C. Church, Associated Oil Company, San Francisco, California
B. H. Harlton, Amerada Petroleum Corporation, Tulsa, Oklahoma
Hedwig T. Kniker, San Antonio, Texas
Moses M. Kornfeld, Atlantic Oil Producing Company, Wichita, Kansas
G. W. Schneider, The Texas Company, Shreveport, Louisiana
Theron Wasson, The Pure Oil Company, Chicago, Illinois
James A. Waters, Sun Oil Company, Dallas, Texas

Paul D. Torrey, K. C. Heald, John M. Muir, and others have also furnished useful information. To all these geologists the writer desires to express his gratitude. He is also under obligations to many subsurface workers in California, Texas, and Oklahoma, who from time to time have shown him their laboratories and methods of work and have discussed orally their problems and the results of their investigations. Free use has been made, finally, of many previously published papers which have a bearing on the subject of this investigation.

[1]Numbers in parentheses refer to papers listed in the bibliography at the end of this paper.

Sidney Powers suggested the writing of this paper and has assisted greatly in securing data for it.

The list of questions sent out concerned sampling methods, treatment of samples, kinds of data sought in studying them, accuracy of correlations attempted, obstacles to better correlations than those now made, scientific and economic results of sample studies to date.

A study of the answers received suggests the order of treatment adopted. It is obvious that Kansas, Oklahoma, and north-central Texas comprise a district (here termed the Kansas district) that differs vastly, in type of work required, from the central Coast Ranges of California. West Texas is a large district differing from the Kansas district much less than from the California district. The Gulf Coast Tertiary and Cretaceous provinces have analogies with California, with many interesting peculiarities of their own. The Rocky Mountain district, finally, has features resembling both Kansas and California. It is therefore possible to give a fair picture of the subject by discussing at most length the Kansas and California districts. West Texas and the Rocky Mountains are discussed more briefly and compared with Kansas. The Gulf Coast is likewise discussed briefly and compared with California. Other areas are treated still more briefly. This plan has the further advantage that the writer, though not an expert in subsurface stratigraphy in any district, has more first-hand information about the two districts chosen for detailed treatment than about any of the others.

KANSAS DISTRICT

Some details of the history of microscopic examination of well samples in Oklahoma are given by Powers in his historical sketch, "Petroleum Geology in Oklahoma" (26). He shows that microscopic fossils were first used in correlating subsurface samples in 1916. J. A. Udden, E. A. Trager, and V. V. Waite made microlithologic studies of well cuttings in Oklahoma and Texas at this time or a little later. Samples were not generally preserved and studied, however, until 1924.

> Micropaleontology became an integral part of the oil business in 1924. Determinations of the age of cuttings and the correlation of sands became a necessary adjunct to most oil companies during this and the following year. Lithology and heavy minerals are also used in coördination with fossil evidence. This work has brought about a reorganization of scouting activities whereby scouts furnish samples and logs of drilling wells each week instead of merely the depth. In 1926 samples were being collected from practically every wildcat well in Oklahoma, Kansas and Texas. Moreover, the drillers have been given more or less instruction by oil companies in the distinguishing characteristics

of formations—some companies have even taken microscopes on the derrick floors to interest the drillers in making accurate well logs (26, p. 20).

Further details, with a discussion of the conditions that existed a few years later, may be found in an interesting paper by Miss Radler (28).

In this district, the general structure is commonly simple, with only local complications. Most of the Paleozoic formations, of hard limestone, compact shale, or well cemented sandstone, are readily distinguishable in the field, and nearly all are remarkably persistent laterally. Large and small fossils occur, but many of them have a wide stratigraphic range. Very many deep wells have been drilled in this district, most of them by means of cable tools.

It is interesting to recall that great strides were made in the subsurface interpretation of this area merely by a study of drillers' well logs. Microscopic work has therefore been devoted to attempts to improve records that were already good. The microscopists have in the main simply done better what the drillers were already doing fairly well. In doing so they have given attention to all available features of their samples, commonly without attempting to specialize in any one feature such as micro-fossils or heavy mineral residues.

As already suggested, most of the well samples available for study are cable-tool cuttings. Outcrop samples are collected and studied from sections in the Arbuckle or Ozark Mountains or elsewhere, to assist in correlating subsurface conditions with those observable in areas where the formations crop out. Most workers feel that too few such studies have been made. All agree that the cable-tool cuttings, taken at intervals of 5-10 feet, are satisfactory for the solution of most of the problems with which they are faced. A few would like more core samples from certain horizons, but others feel that cores are troublesome to study and likely not to be worth their cost. Most of them have little liking for rotary samples.

The general satisfaction felt by all workers with cable-tool cuttings may come as a surprise to those who have not attempted to use them. Some workers feel that too little care is used in collecting samples and all admit that some contamination from higher horizons may occur. With care and good judgment, however, most of the errors that might result from such contamination seem to be avoidable. The character of the formations involved must be an important factor in making possible the satisfactory use of such samples.

The methods used vary with the problem to be solved, with the type of feature disclosed by preliminary inspection of a set of samples, and

with the preference and skill of the individual worker. The chief reliance of most workers, however, seems to be an inspection under the binocular microscope of the cuttings secured from different depths in a well. Further tests and studies include the making of thin sections of *Fusulina*-bearing limestone, the examination of siliceous residues[1] from limestones, of heavy mineral concentrates from sandstones or sandy shales, the identification of many types of large and small fossils, and simple chemical tests. As one correspondent[2] expresses it:

> The most successful stratigraphers in microscopic work in this region do not prejudice themselves to any particular methods, but combine lithology and paleontology as a whole, without undue emphasis upon any one particular ....specialty....

In addition to the generalities already given, it may be worth while to quote a somewhat detailed description[3] of methods used in one laboratory for examination of well cuttings.

> Every sample is first bottled in a two-dram screw-top vial, labeled and filed in numerical order by trays in legal filing cases. This size bottle provides a sufficiently generous sample, is the smallest size easily filled, and may be readily opened. From the bottle a part of the material is placed in a watch glass, acid applied by means of a short glass tube, the reaction observed and the murky fluid washed from the sample into a basin of water. *Every sample* is treated in this manner. The acid instantly removes dust, which water is slow to attack, distinguishes calcareous from non-calcareous material, dolomite from limestone, and tends to break down clay more readily than does water. This abbreviated suffusion with dilute acid is not injurious even to delicate fossils; instead it creates clearer visibility. Clay samples of course require further agitation and rewashing....
>
> After describing the contents, the wet sample is discarded....Our aim in the laboratory is accuracy and speed....Naturally, some subsurface geologists must think our methods not advantageous. Usually these persons object to the discarding of any part of a sample and to the bother of washing the dust from each....Some prefer to wash, dry, and then examine samples....Most laboratories develop their own technique.

[1]Since this paper was submitted for publication, Sidney Powers has called the writer's attention to a recent article by H. S. McQueen (Appendix I, *Missouri Bur. Geol. and Mines 56th Biennial Report*) on the usefulness of "siliceous residues" in recognizing limestone formations, and in zoning them. It is very probable, as Powers suggests, that McQueen's methods will go far toward revolutionizing subsurface work in areas underlain by thick limestone beds.

[2]M. M. Kornfeld, letter dated January 7, 1931.

[3]This passage refers to methods used in a West Texas laboratory, but the samples studied are similar to those commonly available in Kansas and Oklahoma. From letter of Dorothy Ogden Carsey, dated January 17, 1931.

In the sentences omitted from this interesting account, Mrs. Carsey compares the merits and demerits of her own and other methods and gives the reasons for her preference for the methods she uses.

In compiling the data resulting from examination of samples, many workers use printed well-log blanks like those formerly used for comparing drillers' logs. Thus Waters prefers "to plot the species of microfossils and washed residues with lithology." Mrs. Carsey's account is more explicit.

> *All* available recorded sample information is put into graphic or rather *picture* form. Besides plotting sample information by percentages and in colors, we represent fossils and unusual characteristics by variegated symbols and initials on the narrow lefthand margin of the log strip. Variations in size of symbols indicate quantity. The wide righthand margin bears the verbal description which, in the first place, is made comprehensive in as concise a manner as possible. With these strips, which are the ultimate in accumulated information, correlations are simple, visible, and easily reconstructed in picture form....

The correlations attempted have a considerable range in preciseness. Some of them are made "to the foot," others to within 10 or 20 feet or more. Some workers ordinarily try to recognize only important formations, others look for thin members within formations. Most of the writer's correspondents believe that their correlations are considerably more accurate and definite than those commonly made by competent students of megascopic fossils. Such students, in the words of Mrs. Edson,

> see a few fossils at an outcrop or two. We have hundreds of samples and fossils to one of theirs. We see lateral and vertical variations better than they can be seen at outcrops (because of slump and weathering of soft beds).

Of the factors that prevent better correlations than those now current, the chief seem to be the need of more and better fundamental research, and the common necessity for too much haste. The samples available and the methods already developed for preparing them are considered satisfactory. Limited library facilities, poor coöperation between geological and drilling departments, lack of specialized paleontologic and petrographic knowledge on the part of some of the microscopic workers, and poorly prepared or poorly illustrated articles in many scientific journals, are mentioned as other factors which contribute to faulty or uncertain correlations.

Concerning paleogeographic contributions by microscopic workers, the consensus of opinion is that many more have been made than have

been discussed in published form. Published contributions are prevented or delayed chiefly by considerations of oil-company policy. Of papers already published, several have appeared in this *Bulletin*, others in survey publications of the states concerned and elsewhere. A few of them are listed in the bibliography at the end of this paper.

There is general agreement that the economic results secured by sample studies are many and important. Thus, Harlton writes:

Practically every correlation is made by means of micropaleontology.... Nearly 75 per cent of all drilling wells depend on micropaleontology for completion and pipe-setting.

Among the interesting special discussions contributed by workers in the Kansas region, two require consideration here. Mrs. Edson contributed an advance copy of an unpublished paper (13) which, better than any article yet published, discusses the relation of heavy-mineral analysis to other types of microscopic research, and explains the conditions under which such analyses are particularly valuable or even indispensable. In an earlier paper (12, p. 71), the same author summarizes her views as to the uses of heavy minerals as follows.

There is no doubt whatever that heavy minerals serve as a very accurate and practical means of correlating a given sand in a restricted area; that is, within the confines of any one pool. If the sand is thick, say one hundred feet, marked by an unconformity at the top, the heavy minerals will show the presence of zones in the sand; the datum on any one of the sand zones in the different wells in the producing part of the oil pool will show accurately the structural attitude of the sand before it was eroded off at the top. Heavy mineral analyses, then, serve not only to distinguish locally any given sand from the sands above and below it, but their vertical variation is so rapid that they can also be used to find any particular stratum within the sand.

Kornfeld, who has worked or studied in California and on the Gulf Coast as well as in Kansas, contributed a discussion of the differences between microscopic work in Kansas and elsewhere. With a few slight verbal changes and omissions, the passage is as follows.

Concerning the relative adequacy of the microscopic work being done in the Mid-Continent Paleozoic, the Mid-Continent Cretaceous, the Gulf Coast Tertiary, and the Pacific Coast Tertiary, it is my opinion that your observation as to unavoidable circumstances being the cause for such differences as exist, is true. I would group the Gulf Coast and Pacific Coast as one Tertiary province, the Mid-Continent Cretaceous as a second province, and the Mid-Continent Paleozoic as the third province for a consideration of the microscopic work being done in these regions.

....When it is considered that the average worker is faced daily with well samples from the Cambrian, Ordovician, Silurian, Devonian, Mississippian,

Pennsylvanian, and Permian, the stupendous task that awaits the micropaleontologist in this region is realized.

Although unavoidable circumstances are the cause for the major differences that exist, I am inclined to believe that a marked superiority in technical training is held by the Tertiary and Cretaceous micropaleontologists who to a great extent have had not only paleontologic but micropaleontologic training previous to commercial employment. This leads me to state that the name "micropaleontologist" as applied to the average geologist engaged in a study of well samples in the Mid-Continent Paleozoic is a misnomer. In reality most of the workers here are only stratigraphers who happen to have the advantage of the microscope, and whose best success has been secured from lithologic studies.

On the other hand, the real micropaleontologists in this area are those geologists with previous training in micropaleontology, who realize the limitations of lithologic means of correlation and who attempt to use any and all types of fossil organisms available, in conjunction with lithology, for their determinations of age relations. Naturally, the immensity of the field that is covered limits the capabilities of the individual workers. This calls for a greater degree of coöperation than ever before realized between workers in fundamental research in universities and allied workers in commercial pursuits, as well as the encouragement of research in the geological staffs of the larger organizations engaged in the petroleum industry.

WEST TEXAS (PERMIAN BASIN)

West Texas comprises an area in excess of 76,610 square miles or little short of one-half the size of California. Within our division there have been drilled about 4,500 field and wildcat oil tests, on approximately 75 per cent of which we have plotted sample logs, or, as a matter of fact, have all sample information that is available. Also, we have collected drillers' logs in the entire territory. Records were not kept on less than 5 per cent of the wells drilled here.[1]

As compared with Kansas, the West Texas district is similar in structure and in age of buried formations. It differs chiefly in the great variety of facies represented in many formations. Dolomite, sandstone, limestone, salt, anhydrite, red marl, and black shale occur in great profusion and variety.

The situation confronting the subsurface worker in West Texas is well described by Cartwright,[2] and may best be given in his own words.

In discussing microscopic work in West Texas and southeastern New Mexico it should be borne in mind that there are two geologic provinces now being developed, namely the Permian Salt basin, which is of Double Mountain (Permian) age and the "Black Shale basin," which is of lower Permian and possibly Pennsylvanian age. These basins overlap to a certain extent geo-

[1]Dorothy Ogden Carsey, letter of January 17, 1931.

[2]Lon D. Cartwright, Jr., letter of December 17, 1930.

graphically, although the known part of the "Black Shale basin" extends southeast from the Permian basin to the Balcones fault zone.

Microscopic work in the Permian basin is pursued on fairly well established lines, while it is new in the "Black Shale basin." Micropaleontology is of no aid in solving Permian basin problems because no microfossils are gotten in the vast majority of the cuttings. Micropaleontology is of value in the "Black Shale basin" because microfossils are gotten in cuttings, and faunas can be traced from well to well.

In the Permian basin the formations drilled are usually Double Mountain (Permian) and younger. In the "Black Shale basin" the formations drilled are Double Mountain and older down into the Ordovician, and naturally a different technique will develop to handle these older formations.

My present technique is: for Permian basin stratigraphy, preparation of accurate percentage lithologic logs without much attention to details of lithology such as texture, color, et cetera, of each rock type; for "Black Shale basin" post-Siluro-Ordovician rocks, slightly more comprehensive lithologic descriptions with percentages of different rock types tested and plotted graphically, and close study of microfaunas; for Siluro-Ordovician rocks, quite comprehensive lithologic descriptions to establish criteria for identifying some beds by lithology in other wells, and use of fossils where available.

This reflects my opinion that lithologic details vary greatly by gradation in the Permian, may be more constant in the Pennsylvanian, and are possibly quite constant in Siluro-Ordovician rocks.

For other interesting details of correlation methods in use in the West Texas basin and the kind of results that are being obtained, two papers by Cartwright (3, 4) should be consulted.

During the Permian, West Texas was evidently an area of tropical sea and desert lands. Coral reefs, black muds, red lagoonal muds, marine and continental clastic sediments, and varied chemical deposits were laid down contemporaneously. Most such sediments are naturally not now being deposited where many of the West Texas geologists can observe the processes involved. Many of them, as a matter of fact, do not even crop out so that they can be studied at the surface. When penetrated by the drill, they are so far beyond the comprehension of the drillers that their interpretations have less than ordinary value for the geologist who wishes to interpret them. Under the circumstances, it is difficult to see how we should ever have learned much about the distribution and interrelations of these beds if the finding of oil in them had not led to the drilling of thousands of wells and to the study of samples from most of them by many careful workers. Most of the data have not been released as public information, and many facts have probably not even been completely and satisfactorily interpreted. The data are being accumulated and preserved, however, and will no doubt furnish

the basis for valuable paleogeographic investigations that may be published in the future.

To the question "How much has microscopic work improved correlation-making in your territory?" Cartwright suggests a modest 60-85 per cent. Mrs. Carsey writes as follows.

> Microscopic work has made correlation possible in our territory. From drillers' logs the following are indistinguishable: Cenozoic from lower Comanche, a part of the latter from Triassic or Permian, the latter two from each other, zones within the Permian Red-beds, anhydrite from dolomite or limestone.

Both of these workers agree that further improvement in correlations could be obtained if a greater amount of fundamental research were completed. Cartwright thinks that some completely cored wells would help greatly, and Mrs. Carsey mentions limited library facilities as an unfavorable factor.

The economic results sought by means of microscopic work in this province are many and varied. The chief aim is the finding of favorable structurally high areas, by correlating formations in widely separated wildcat wells.

ROCKY MOUNTAIN DISTRICT

The Rocky Mountain district is so large and so varied that it is difficult to discuss as a unit. The following paragraphs furnish only an inadequate summary of data furnished by Coffin and Waldschmidt.

The samples used consist of cable-tool cuttings, 95 per cent; cores, 4 per cent; rotary ditch material, 1 per cent. Outcrop samples are used much as in the districts previously discussed. The chief aim of the sample examinations is the making of comprehensive lithologic descriptions. Micro-fossils and heavy minerals are ordinarily not studied intensively. In general, the microscope has so far been used only where other methods failed.

> In many cases we find that having used it and having certain markers pointed out for us, we then can proceed without the use of a microscope. This is especially true where it is merely a matter of picking up certain lithological breaks and is especially applicable to certain parts of the Cretaceous series.
>
> Microscopic work has undoubtedly improved our methods of correlating ....especially in the basal part of the Cretaceous where there is no other means of correlation than that provided by microscopic study. This statement applies to that portion of the Cretaceous generally referred to as Niobrara and Benton.[1]

[1] R. Clare Coffin, letter of February 9, 1931.

Waldschmidt considers the time element the chief obstacle in the way of making better correlations, and believes that at present the correlations made by microscopic methods are equal or superior to those commonly made in the Rocky Mountains by competent students of the larger fossils. The superiority of the microscopic method, in his opinion, lies in the fact that it does not neglect the physical and mineralogical characteristics of the sediments containing the fossils.

Concerning the results of the work already completed, Coffin states that the facts revealed by microscopic research would undoubtedly contribute much to the paleogeography of the Rocky Mountain area, but that up to the present no publications on this subject have used these facts. He considers that the work has been invaluable in revealing the approach of the drill toward producing horizons in wells, in supplying data for correct setting of casing, and in furnishing correlations within producing fields. Furthermore,

> we have found microscopic work involving heavy mineral separation of especial value in correlating beds encountered in core drilling to shallow depths for structure.

Coffin closes his letter with what he characterizes as a "rather sweeping statement," which summarizes the situation well.

> In no problem where we have had sufficient urge have we found it impossible to improve our knowledge by microscopic study where other methods failed. . . .
>
> It might interest you to know that we feel sufficiently confident of this type of work to justify the filing of cuttings from any wildcat well in our territory where the problems have not already been worked out. We do not undertake the study of all cuttings, but we feel that the saving of a permanent record which can be studied if necessary is economically profitable.

CALIFORNIA

From the geologist's point of view, California presents a strong contrast to Kansas, and there is, of course, a parallel difference in the development and present status of microscopic subsurface work. The formations of the California oil fields are nearly all Tertiary, limestone is almost absent from the section, most of the beds and even formations are extremely lenticular, and areas of simple structure are few. In the areas of supposedly simple structure, it might be more accurate to say that there are no outcrops.

Even when cable-tool drilling was the rule in the Coast Ranges, drillers' logs were so inadequate that, except in closely drilled areas, subsurface work languished. With the advent of the rotary drill it

threatened to disappear altogether. Even microscopic work of the kind practiced early and successfully in Illinois and elsewhere proved inadequate and comparatively futile in California. It was not until the introduction of the practice of taking many cores, a practice that has become increasingly prevalent for approximately a decade, that conditions began to look more promising. To an optimistic minority there seemed, even so long as 10 years ago, to be a possibility of learning something from an intensive study of the many cores that were becoming available. Success was slow and partial at first, and many mistakes were made. Only during the last 5 years, in fact, can it be said that successful microscopic correlations have become the rule in California. This success had to wait on contributions by such specialists in the *Foraminifera* as Cushman and Galloway, on the efforts at self-education of a considerable group of energetic workers, on the development of a specialized technique, and on the accumulation of a very large number of data by the combined efforts of commercial and university research workers.

The most successful correlations have been made by intensive studies of foraminiferal, diatom, and heavy-mineral assemblages. Microlithologic studies, of the type practiced in Kansas and elsewhere in areas of Paleozoic rocks, have been comparatively unsuccessful. At present, foraminiferal work has progressed so far as almost to displace all other types of subsurface work, except within producing fields.

Heavy-mineral assemblages seem to have been first used commercially by the Marland Oil Company of California in 1925. At that time geologists of this company succeeded in correlating sections of lake beds penetrated by 29 shallow core holes in northwestern Kern County (29). A little later the subsurface workers of the Union Oil Company found heavy-mineral residues of value in correlating well samples from the Richfield oil field of the Los Angeles basin. Similar work has also been done from time to time in several areas by Paul P. Goudkoff (20), and probably by others. It is now commonly believed that heavy-mineral analysis is too expensive to be used except under special circumstances. Its value is generally recognized, however, as a means of securing paleogeographic data.

The only worker now known to be using diatoms in oil-company work in California is G. D. Hanna. He has made intensive studies of diatom floras ranging in age from Upper Cretaceous to Pliocene. He finds that many of them are distinctive and widespread, and have a limited vertical range. Although the treatment of samples for diatom study is extremely specialized, Hanna writes as follows.

As to the comparative ease or difficulty of preparation of samples for study of the different classes of fossils, there does not appear to be much variation. An average sample may be prepared for examination of the diatoms in about the same amount of time as would be required to prepare it for *Foraminifera* or any other group.

In view of Hanna's experience it seems probable that the general neglect of diatoms by most California subsurface workers results (1) from their unfamiliarity with the vast literature of diatoms and with the specialized technique needed to study them, and (2) from their success in solving the great majority of their problems by restricting their studies to the more widely distributed *Foraminifera*.

In striking contrast to the conditions described in the foregoing paragraphs for other districts, nearly all the samples now used by California micropaleontologists are taken from cores or from outcrops. Hanna and Church report as follows.

> Routine examinations and reports are made on:
> a. Cores, 90 per cent.
> b. Cable tool cuttings, negligible.
> c. Rotary ditch material, negligible.
> d. Surface samples, 10 per cent.
>
> Outcrop samples are studied in exhaustive detail in some cases, in order to establish a section which will be recognizable in its integral parts in material derived from wells in the same region.

The conditions found among other laboratory workers in California are very similar to those described in this passage. The relatively large amount of work devoted to surface samples depends, of course, upon the geological conditions. A geologist familiar only with Mid-Continent conditions may find it difficult to realize that in many California oil fields one who stands at the mouth of a well 5,000-8,000 feet deep can see at a distance of a few miles a canyon wall in which the whole well section is exposed. In view of the rapid lateral changes common in most areas, this favorable feature is very fortunate. Most Coast Range counties, in fact, have several strikingly different Tertiary sections, each of which must be carefully measured and studied and correlated with the others before satisfactory well correlations are possible. This condition, together with the frequent calls for help from puzzled field geologists in most localities, accounts for the large proportion of work devoted by most California laboratories to the examination of surface samples.

The methods used in preparing core samples and in studying their foraminiferal content vary with the preferences of different workers and with other factors. In general, after parts of each core sample are

soaked in water, they are washed vigorously on a set of screens to clean and concentrate the *Foraminifera*. In some laboratories the washed material is examined while wet; in most of them, after drying. The extent to which samples are exhaustively picked and their contents preserved in permanent slides varies, of course, but is always great as compared with the practice common in other districts. The greater complexity of the problems to be solved, and the difficulty of finding any adequate solution even by the most thorough study, are the reasons given for the difference.

Few descriptions have appeared in print. Some of the contributions to this subject by G. D. Hanna and others are listed in the bibliography (9, 22). Of them he writes:

> Our methods were published several years ago, but modifications have necessarily since been made.

In a region so large and geologically complex as the Coast Ranges, the definiteness of the correlations that are possible is subject to a wide range. In most of the more thoroughly studied formations several definite zones can be recognized, and some of these have a great areal extent. Some of the zonal and formational contacts are sharp, others are gradational. In most satisfactorily cored wells, the stratigraphic position of the drill at any depth need not be uncertain by more than 100 feet, unless there are no wells or outcrop sections within a distance of several miles. In such places, greater uncertainty may be introduced by the impossibility of proving the absence of great changes in thickness of members or formations.

For better correlations the chief need, in California as elsewhere, seems to be for fundamental research. G. D. Hanna believes that the

> closeness of correlation is in direct ratio to fundamental research on the microscopic constituents of the sediments and will continue so until vastly more detailed studies have been made and published.

He mentions, furthermore, that great progress would be possible if the results of researches already completed could be published more promptly. This difficulty would be even more serious if it were not for the fact that the majority of the subsurface workers live and work within a comparatively small area, and are in frequent communication with one another.

As to the relative value of large and small fossils for correlation purposes, it is the general view of oil company workers, at any rate, that the small fossils are superior. Hanna, who has had wide experience with both classes, says

with the greatest emphasis that the latter are the more dependable. In making this statement no reflection is cast on the work of any other student, but it is based solely on the factors involved in correlation. Chief among these are conditions of preservation, relative abundance, and ease of preparation for study. For instance, in about thirty minutes, as many *Foraminifera* can be extracted from a sample in a thoroughly cleaned condition as could be obtained from an average surface outcrop of comparable material in several months' work, if *Mollusca* only were being obtained. The same applies with greater force to diatoms and silicoflagellates. The microfossils are so much more often well preserved in the sediments than are the macrofossils, that the latter are totally ignored in many laboratories; too much time is usually required to prepare and study them. Moreover, it is rare that determinable large fossils are found in cores taken in drilling wells.

The contributions of micropaleontology to paleogeography in California have been considerable, though here, as elsewhere, most of the investigations have not yet been adequately published. As the largest Tertiary province without outcrops in California, the San Joaquin Valley has naturally been the place for most of these newer investigations (32).

Of the economic results commonly sought, the securing of information for determination of the proper position at which to set pipe is least important, because the information can ordinarily be secured more readily by other means. The most important duty of the micropaleontologist is to assist in the search for new oil fields. In the words of Hanna and Church:

> This work falls into two classes: (1) The determination of age and zonal position in surface outcrops of districts where field mapping is being carried on; (2) the determination of the same for various points in prospect wells. This information is used to check field data as to structure, and also to determine when all possible oil-bearing horizons have been passed.

The contribution of micropaleontology to stratigraphy in California has already been very great, and the future seems promising. Already it is becoming possible to define such comprehensive and indefinite names as "Modelo," "Monterey," "Temblor," "Jacalitos," and "Fernando" in terms of the foraminiferal zones represented in their type localities and elsewhere. One of the chief causes of concern at present, in fact, is the academic question of what to do with these time-honored but overlapping names. The importance of the progress that has been made in this matter is likely to be undervalued by those who have never seriously tried to understand California geology. They should remember that only a few years ago the geologists in southern California looked forward with mingled hope and skepticism to the time when it would become pos-

sible to trace a single horizon positively from well to well throughout the Los Angeles basin (area less than 1,000 square miles). That the stratigraphic knowledge now available, which is new and yesterday was unsuspected, should be more interesting to local geologists than details of structure, the greatest variety of which has been available to them all their lives, is certainly not surprising, however unfortunate it may be.

GULF COAST TERTIARY AND CRETACEOUS DISTRICTS

The history of micropaleontological work in the Gulf Coast of Texas and Louisiana is sketched in an interesting article by Schuchert (31). He points out that several Texas workers began to study *Foraminifera* from well samples in 1917 and at the time he wrote (1924) had already demonstrated to the satisfaction of themselves and their employers their ability to make correlations that were vastly superior to any that had been made earlier. J. A. Udden contributed very much to the pioneer work in this field, and helped in the training of several of the early workers. In 1920 E. T. Dumble organized the first oil-company laboratory devoted to Gulf Coast micropaleontology. The Humble Oil and Refining Company, at the instigation of Wallace Pratt, opened the second laboratory a month later. The Texas Company laboratory, under the supervision of R. F. Baker, came into existence in 1921. Miss Esther Richards, now Mrs. Paul L. Applin, Miss Alva C. Ellisor, and Miss Hedwig T. Kniker were in charge of these laboratories and worked together on much of the preliminary research.

The statement of Wallace Pratt, as quoted by Schuchert (31, pp. 540-41), is particularly illuminating as to the conditions before and after the beginning of micropaleontological work.

> We started (work in micropaleontology) with practically no information as to the character of the geologic section beneath the surface.... To-day, after comparatively brief experience, we can state with fair accuracy the age and character of our reservoir beds, the age and character of our source rocks, and we can know in advance what character of material we may expect to penetrate at a given depth.... We have been able to correlate zones of 400 or 500 feet thickness over areas hundreds of miles in extent.....

In a recent letter, Miss Ellisor gives further details.

> Ten years ago it was believed that no *Foraminifera* existed in the salt dome region of the Gulf Coast because the wells up to that time did not go much below 3,000 feet.
>
> In 1920 the first *Foraminifera* were discovered in the Gulf Coast by the Humble Company, when their wells reached the Oligocene in Goose Creek and West Columbia.

> At first the *Foraminifera* were used to mark the contacts of the formations, particularly in wells on the salt domes. Later *Foraminifera* were used to determine the age of the formations in the wells of the Cretaceous along the Balcones Escarpment. After a while we began to divide the formations into zones on the basis of *Foraminifera*. Then we began to correlate surface formations with the aid of *Foraminifera*.
>
> After ten years of detailed study we find that *Foraminifera* have a very limited vertical range in the geologic column, and a wide geographic range. Faunal associations remain constant over wide areas so that zones and members of a formation can be traced across the state of Texas into Mexico on one hand and across Louisiana into Mississippi and Alabama on the other.
>
> In cases where we lack *Foraminifera* we have to depend upon lithology. ....Up to date no safe conclusions have been arrived at by using heavy minerals in the Cretaceous, Eocene, and younger sediments.

The samples available to Gulf Coast workers seem to have a considerable range, which depends partly on the district, partly on the policy of the company doing the drilling. From Cretaceous and early Tertiary horizons, M. A. Hanna secures about half his samples from cores and half from rotary cuttings. From the coastal country (later Tertiary) he receives little ditch material and depends largely on cores and bit samples.

> Probably 75 per cent of our samples from the coastal district are cores, often badly contaminated.

South and west from Wharton County, Texas, however, the samples from later Tertiary regions are more nearly comparable with those from regions of early Tertiary and Cretaceous rocks. Fairly extensive collections of outcrop samples have also been made and studied by Hanna and his assistants.

Waters also studies outcrop samples on occasion, but reports that practically all the well samples which he receives from East Texas and the Gulf Coast are rotary ditch material. He finds them "not entirely satisfactory." Schneider, writing from the Louisiana point of view, makes the following statement.

> In drilling all wells we strongly recommend coring instead of cuttings for accurate work. In this region where the formations contain a scant amount of marine life we find contamination of the underlying beds in drilling by the cuttings which fall in from above....In the salt dome area....the Miocene formations appear to be less fossiliferous than in Texas and the formations have more or less similar lithologic characteristics, and we find coring essential.

To illustrate his view, Schneider cites a case in Mississippi where a miscorrelation from cuttings postponed for several years the discovery of an oil field. The evidence of a single core, if one had been taken, he

thinks would have prevented the mistake and the delay. M. A. Hanna agrees that a few completely cored wells, especially in regions of later Tertiary rocks, would be of material benefit, but thinks that there is at present a tendency on the part of several companies to core more continuously than before. More and better cores are becoming available all the time. Cores supplemented by cuttings furnish the best combination at present. Miss Kniker reports that she has used rotary bit samples from the Gulf Coast which were just as satisfactory as cores. Rotary cuttings she considers to be very unsatisfactory.

In studying samples, the Gulf Coast workers depend chiefly on *Foraminifera*, but make casual or occasional observations of other features of many kinds. In post-Jackson formations, according to M. A. Hanna, mineralogical data increase in importance. The treatment of samples seems to be more or less standardized, and does not differ greatly from that used in California. In some laboratories, however, the amount of speed with which the samples are handled and studied is many times as great as that attained in any California laboratory.

Of the correlations that are being made, M. A. Hanna writes as follows.

> We attempt in our correlations to carry them down to exactness, even to feet. A number of our contacts are sufficiently sharp to allow this precise work. We have found it necessary to split up many of the formations into small units, which units as yet remain unlisted in the literature. These may be based on fossils, or they may be strictly mineralogical.

All those familiar with the subject agree that no comparison is possible between the correlations now currently made and the best that could be done in former days when only drillers' logs were available.

The only difficulty in making better correlations, in Hanna's opinion, is the time factor. He would also like more and better cores, but believes that they are less essential than more time in which to study those now available. He believes that the only way to proceed is to employ more men, some to make the hasty routine determinations that are always necessary, others to make investigations of a more fundamental nature. He mentions objections to having work of the latter type done by educational and research institutions and concludes that most of it will eventually have to be done by the oil companies themselves.

All of the Gulf Coast workers consulted mention important contributions to regional geology and paleogeography which have been made by means of microscopic investigations. The greater number of these have not yet been discussed in published form. A few of the others are

cited in the bibliography (1, 14, 15, et cetera). The economic results obtained are considered by all to have been very valuable and to belong to all the categories to which subsurface work could possibly contribute.

MICROSCOPIC WORK IN OTHER AREAS

So far as can be learned, not much microscopic work is being done at present east of Mississippi River. K. C. Heald, writing from the office of the Gulf Companies in Pittsburgh, says:

> I know of very little such work in progress.....As you know, much of the development is done by individuals and very small companies.....
>
> We have one man in this office who devotes part of his time to that work, studying both well cuttings and outcrop material. In all our microscopic work we endeavor to establish diagnostic criteria from outcrop samples rather than to depend entirely upon building up our information from well cuttings.

J. Ernest Carman writes that the oil companies operating in Ohio seldom save samples, and still more rarely study them in any worthwhile way.

Paul D. Torrey[1] contributes some additional information on conditions in Pennsylvania and New York.

> In regard to the study of cores and cuttings for purposes of identifying various horizons encountered in drilling, I can state that we have used them to a considerable extent. The age of the Bradford sand was first definitely established by studies of fossils from cores of the sand, and the marine origin of the Venango group of sands was discovered in the same manner. In New York state we keep cuttings of practically every wildcat well drilled and these have been most valuable in studies of convergence and in establishing centers of sedimentation. Our paleontologist, John T. Sanford, of the Buffalo Museum of Natural Science, has made very careful studies of cuttings from Silurian formations and has been able to make some very definite correlations by the use of ostracods and other micro-fossils.
>
> We have made no attempt to use heavy minerals as a means of identification, but at the present time Professor Honess of the Pennsylvania State College is making a most exhaustive study of the various minerals in Pennsylvania oil sands. I understand, however, that his work is not yet sufficiently advanced to enable the publication of a preliminary report.

In the new Michigan fields, The Pure Oil Company is making good use of samples in subsurface studies. Theron Wasson states that most of the samples are cable-tool cuttings. These are washed in the laboratory at Saginaw, Michigan, and are examined chiefly for lithologic, but partly for paleontologic information. Similar work is being done by the Michigan Geological Survey.

[1]Letter of February 21, 1931, addressed to Sidney Powers.

Although it does not come within the scope of this paper, it may be noticed that micropaleontology has been widely used in other parts of North and South America. T. W. Vaughan, J. A. Cushman, W. S. Adkins, and E. A. Trager are among the men who worked in Mexico between 1920 and 1925, and there have been many other workers since. Similar studies, and some interesting mineralogical investigations, have been made in Venezuela, in Canada, and elsewhere.

In the eastern hemisphere the use of small *Foraminifera* seems to have been less common than in the United States. Excellent heavy mineral studies, some of them of well samples, have occasionally been made for many years, however, and the larger *Foraminifera* have long been used in many kinds of stratigraphic investigations.

CONCLUSIONS

In the foregoing pages a sketch has been given of the gradual rise of microscopic subsurface work in several typical oil districts of the United States. Beginning with casual and occasional investigations about 15 years ago, the work became systematized in most districts 5-10 years ago, and is at present being carried on energetically and successfully in all.

The methods used differ somewhat with the character of the rocks penetrated, the type of sample available, and the nature of the problems to be solved. Micropaleontology is of most importance in areas of Mesozoic and Cenozoic rocks; microlithology in areas of Paleozoic rocks and in the Cretaceous of the Rocky Mountains. A need for a greater amount of fundamental research is felt by the workers in all the districts investigated.

So far as an amateur can judge from the outside, the amount of fundamental research already accomplished in each geological province tends to approximate the minimum that will permit the hope of a reasonable amount of success. This minimum is great enough, fortunately, so that important contributions to geology have already resulted in all the provinces reviewed. Greater contributions, and likewise greater economic results, will no doubt be secured when the growing complexity of the problems to be solved results in the application of a greater amount of research. Enough has been done so far to demonstrate that there is practically no limit to the accuracy of the correlations that are possible if their value seems to justify the expense. And accurate correlations furnish the necessary basis for worth-while studies of regional structure and paleogeography.

The old arguments as to the value of *Foraminifera*, heavy minerals, and other microscopic objects for correlation have largely subsided. Most of the people interested in the subject are too busy using these criteria to argue about their usefulness. It is generally admitted that *Foraminifera*, for example, have certain disabilities—as do all other criteria for correlation—but the fact remains that they can be used in making correlations that must undergo severer tests than those to which most correlations of the older type were ever subjected. Those who made gloomy predictions of the possibilities of correlating by means of *Foraminifera* seem to have underestimated the importance of the advantages commonly possessed by students of well samples. Among these advantages are the possession of many immensely thick and well distributed sections and the freshness and close spacing of the samples representing them. The old geological ideal of a "geogram" (25) for each formation studied has in fact rarely been so nearly attained as by subsurface workers in those districts of the United States where intensive drilling for oil has been carried on in recent years.

BIBLIOGRAPHY

Besides the papers cited in the text, a few others that illustrate some of the features discussed are listed here. No references are given to the *Journal of Paleontology*, which anyone interested in the subject of the foregoing paper will naturally examine. Many interesting and valuable papers published elsewhere are also omitted.

1. E. R. Applin, A. C. Ellisor, and H. T. Kniker, "Subsurface Stratigraphy of the Coastal Plain of Texas and Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 1 (January-February, 1925), pp. 79-122.

2. F. L. Aurin, G. C. Clark, and E. A. Trager, "Notes on the Subsurface Pre-Pennsylvanian Stratigraphy of the North Mid-Continent Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5, No. 2 (March-April, 1921), pp. 117-53. This was one of the most important of several interesting early papers based on the study of well samples. It gave a great impetus to this type of investigation.

3. Lon D. Cartwright, Jr., "Subsurface Correlation Methods in the West Texas Permian Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 2 (February, 1929), pp. 171-76.

4. *Idem*, "Transverse Section of Permian Basin, West Texas and Southeast New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 8 (August, 1930), pp. 969-81. A striking synthesis of results secured from sample studies in West Texas.

5. C. B. Claypool and W. V. Howard, "Method of Examining Calcareous Well Cuttings," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 12 (December, 1928), pp. 1147-52.

6. J. A. Cushman and E. R. Applin, "Texas Jackson *Foraminifera*," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 2 (February, 1926), pp. 154-89.

7. J. A. Cushman, "The Use of *Foraminifera* in Geologic Correlation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 4 (July-August, 1924), pp. 485-91.

8. Robert H. Dott, "Notes on Pennsylvanian Paleogeography with Special Reference to South-Central Oklahoma, *Oklahoma Geol. Survey Bull. 40-J* (Norman, 1927). One of the several recent bulletins issued by the Oklahoma Geological Survey and the Bureau of Economic Geology of Texas, which give an amount of regional subsurface information that could hardly have been imagined in the days of well-log subsurface work.

9. Herschel L. Driver, "Wet Method of Foraminiferal Examination," *Micropaleontology Bulletin*, Vol. 1, No. 2 (1926), p. 2.

In the same volume, No. 3, p. 14, the editor gives a brief discussion of Driver's article, citing the adverse opinion of Arthur Earland. The dispute between advocates of the wet and dry methods is not yet settled.

Many other articles in the *Micropaleontology Bulletin*, which is issued by the students of Stanford University, give data of interest in connection with subsurface work in California.

10. E. T. Dumble, "A Revision of the Texas Tertiary Section with Special Reference to the Oil-Well Geology of the Coast Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 4 (July-August, 1924), pp. 424-44. One of the pioneers of oil geology describes well sections as known from sample studies which he had helped greatly in promoting.

11. Charles R. Eckes, "Description of Cuttings from the Duffer Wells," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1910), pp. 39-40. A very early example of the use of the microscope to improve the log of a Mid-Continent well.

12. F. C. Edson, "Heavy Mineral Work in the Mid-Continent Region," *Report of the Committee on Sedimentation, 1928-1929* (Washington, 1930).

13. *Idem*, "Correlative Methods used in the Mid-Continent Oil Field," paper read before Oklahoma Academy of Science, Nov. 28, 1930.

14. Alva Christine Ellisor, "Coral Reefs in the Oligocene of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 10 (October, 1926), pp. 976-85.

15. *Idem*, "The Age and Correlation of the Chalk at White Cliffs, Arkansas, with Notes on the Subsurface Correlations with Northeast Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 8 (November, 1925), pp. 1152-64.

16. J. J. Galloway, "Methods of Correlation by Means of *Foraminifera*," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 6 (June, 1926), pp. 562-67.

17. F. M. Getzendaner, "Geologic Section of Rio Grande Embayment, Texas, and Implied History," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 11 (November, 1930), pp. 1425-38. Another example of the type of regional study, based on studies of field and well data, that is becoming common in the Mid-Continent.

18. M. I. Goldman, "Lithologic Subsurface Correlation in the Bend Series of North-Central Texas," *U. S. Geol. Survey Prof. Paper 129-A* (Washington, 1922), pp. 1-22.

19. *Idem*, "Testing and Adjusting the Binocular Microscope, and Suggestions on the Use of the Microscope in General," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 1 (January-February, 1925), pp. 175-79.

20. Paul P. Goudkoff, "Correlative Value of the Microlithology and Micropaleontology of the Oil-Bearing Formations in the Sunset-Midway and

Kern River Oil Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 5 (May, 1926), pp. 482-94.

21. G. Dallas Hanna, "Smaller *Foraminifera* for Stratigraphy," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 2 (March-April, 1924), pp. 246-50.

22. G. Dallas Hanna and H. L. Driver, "A Study of Subsurface Formations in California Oil Field Development," *California State Mining Bur. 10th Ann. Rept.* (State Oil and Gas Supervisor), Vol. 10 (1924), No. 3, pp. 5-26, 10 text figures.

23. J. V. Howell, "Notes on the Pre-Permian Paleozoics of the Wichita Mountain Area," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 6, No. 5 (September-October, 1922), pp. 413-25. Reproduces 24 of Hirschwald's microphotographs to illustrate textural types of limestones, and discusses their application to subsurface problems of southwestern Oklahoma.

24. Edgar Kraus, "Logging Wells Drilled by the Rotary Method," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 5 (September-October, 1924), pp. 641-50. Describes sampling methods that are considered to be satisfactory for use in making sample logs.

25. H. B. Milner, *Sedimentary Petrography* (London, 1929), p. 6.

26. Sidney Powers, "Petroleum Geology in Oklahoma," *Oklahoma Geol. Survey Bull. 40-G* (Norman, 1926).

27. *Idem*, "Reflected Buried Hills and their Importance in Petroleum Geology," *Econ. Geol.*, Vol. 17 (1922), pp. 233-59.

28. Dollie Radler, "Micropaleontology in the Mid-Continent Region," *Report of the Committee on Sedimentation, 1928-1929* (1930), p. 68.

29. R. D. Reed and J. P. Bailey, "Subsurface Correlation by Means of Heavy Minerals," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 4 (April, 1927), pp. 359-68.

30. W. I. Robinson and W. J. Eldridge, "A Method for Correlating Gumbos," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 5 (August, 1925), pp. 906-10.

31. Charles Schuchert, "The Value of Micro-Fossils in Petroleum Exploration," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 5 (September-October, 1924), pp. 539-53. Includes many notes on the early history, methods, and results, of micropaleontological work on the Gulf Coast of Texas.

32. J. A. Taff and G. Dallas Hanna, "A Geologic Section in the Center of the San Joaquin Valley, California," *Proc. California Acad. Sci.*, Fourth Ser., Vol. 16 (1927), No. 16, pp. 509-15. Description of a nearly complete Tertiary section from a part of California the stratigraphy of which had previously been entirely unknown. Data from well samples.

33. E. T. Thomas, "An Aid to the Study of *Foraminifera*," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 3 (May-June, 1925), pp. 667-69.

34. E. A. Trager, "A Laboratory Method for the Examination of Well Cuttings," *Econ. Geol.*, Vol. 15 (1920), pp. 170-76.

35. J. A. Udden, "Characteristics of Some Texas Sedimentary Rocks as Seen in Well Samples," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5, No. 3 (May-June, 1921), pp. 372-85. A summary of some lithologic data on the formations of Texas, as secured from microscopic study of well cuttings.

36. J. A. Udden and V. V. Waite, "Some Microscopic Characteristics of the Bend and Ellenburger Limestones," *Texas Univ. Bull. 2703* (1927).

37. J. A. Udden, "Some Deep Borings in Illinois," *Illinois State Geol. Survey Bull. 24* (1914).

38. T. Wayland Vaughan, "On the Relative Value of Species of Smaller *Foraminifera* for the recognition of Stratigraphic Zones," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 7, No. 5 (September-October, 1923), pp. 517-31. An interesting statement of the pitfalls to which the student is exposed who attempts to use the smaller *Foraminifera* in making correlations. In spite of them, these organisms have been found very useful for correlations even throughout considerable distances.

FACTORS GOVERNING ACCUMULATION OF OIL AND GAS IN MIRANDO AND PETTUS DISTRICTS, GULF COASTAL TEXAS, AND THEIR APPLICATION TO OTHER AREAS[1]

O. L. BRACE[2]
San Antonio, Texas

ABSTRACT

The conditions causing the commercial occurrence of oil and gas in the recently discovered fields of the Pettus district, Bee County, Texas, show a striking similarity to those surrounding the older and better known fields of the Mirando district, 100 miles farther southwest. The productive sands in both districts are confined to a stratigraphic section, limited by basal Frio sediments above and by middle Yegua sediments below, which is mainly of Fayette age.

In the Mirando district, accumulation has occurred in narrow strike lenses, formed under conditions of shore-line deposition, in which gradations in porosity have formed traps. Source material, from which the oil and gas were derived, was deposited within, or adjacent to, the present producing horizons. True deformation is ordinarily absent, although folding or fracturing may, in some places, have exerted a minor influence.

Present knowledge of conditions at Pettus indicates that the same factors were primarily the cause of the oil and gas segregation in this area. In the Pettus field proper, accumulation occurs within a lensing sand which follows a definite strike trend. There is no evidence of positive structural influence.

The conclusion is reached that, within the upper Eocene section throughout the inner margin of the Gulf Coastal Plain, strata of basal Frio, Fayette, and upper Yegua age contain differences in porosity sufficient to trap oil and gas, in the absence of structural influence. The following of established strike trends will prove the most effective means of locating such pools.

INTRODUCTION

The past season has witnessed a revival of interest in the oil and gas possibilities of the zone of upper Eocene sediments bordering the Gulf Coastal Plain of Texas. For many years the productive character of this group of rocks has been recognized, but development has been confined mainly to the southwestern area of their occurrence in the Mirando district. In this area, which embraces Webb, Zapata, Jim Hogg, and Duval counties, fields have been developed at shallow depths in sands of Yegua, Fayette, and Frio age. Contemporaneous with the development of these

[1]Read by title before the San Antonio meeting, March 19, 1931. Manuscript received, March 2, 1931.

[2]Corana Petroleum Company, Corsicana, Texas.

fields, there has been a limited amount of exploration of these beds across the entire state, but it was only after the recent discovery of an important oil field in sands of Cockfield age at Pettus, Bee County, that systematic exploration was commenced.

The drilling which resulted in the discovery of the Pettus field was inspired, according to the best information available, by the presence of large quantities of shallow gas in water wells. In several deep tests in this vicinity, encouraging amounts of gas were encountered, and continued drilling led to the discovery of oil. As ordinarily happens in large non-productive areas, the discovery of commercial oil starts much speculation about the cause of accumulation. At Pettus, the absence of definite surface or subsurface structural data made this problem more complex. Explanations of the type of trap involved ranged between faulting, presumably of the Luling type, and closed folding. The true explanation of these conditions was not advanced until sufficient drilling had been done to outline definitely the productive sand body.

For several years, the writer has been gathering stratigraphic and structural data on the Mirando district. Contour maps and cross sections have been constructed, presenting a detailed picture of structural conditions and of the lithology of the stratigraphic belt in which oil and gas occur. This material has permitted the formulation of definite conclusions about the fundamental factors governing the formation and accumulation of oil and gas. At the beginning of this investigation, it was uncertain that these factors could be applied outside the Mirando district, but recent developments have strengthened the idea that fields of the Mirando type may be anticipated wherever the locally productive stratigraphic belt occurs in like relationship to the Coastal Plain.

With the discovery of the Pettus field and the development of the Bee County area, the writer was impressed with the possibility of a local repetition of the Mirando type of occurrence. Not only are the oil- and gas-bearing sands stratigraphically within the zone of production at Mirando, but the attitude of the sand in the Pettus field and the relationship of this field with the other productive areas in Bee County show a striking similarity to those conditions in the southwestern region.

It is the recurrence of those conditions which have heretofore largely characterized one district, that leads to the belief that a review of the essential details of the structure and stratigraphy of the Mirando district may help solve an important geological problem. In this paper, therefore, the review of these data is confined to the productive area of the Mirando district, in the hope of applying the conclusions to the zone of equivalent stratigraphy northeastward across the state.

HISTORY OF DISCOVERY

A brief history of the discovery of the upper Eocene fields of the western part of the Texas Coastal Plain is given because of the significant influences which led to most of these discoveries.

In 1908, gas was discovered in the Reiser area, Webb County, by a rancher drilling for water. By the year 1910, deeper drilling had located several sands of marked potentiality, and a flow sufficient to supply the city of Laredo had been developed. In 1913, ranchers drilling for water in Zapata County brought about the discovery of the Charco Redondo field when a 5-barrel well was completed at 160 feet. By 1914, twelve producing wells had been completed. In 1916, signs of depletion in the Reiser gas field led the Border Gas Company to extend its line to the Jennings ranch, Zapata County, where gas had been discovered in a water well. The development of one of the largest gas fields in the region resulted.

In 1920, a chance location in Zapata County led to the discovery of the Mirando Valley field. The discovery well was located at the base of the Reynosa escarpment and this fact is of considerable significance in its relation to future locations and discoveries. In the following year the Schott, Mirando City, and Carolina-Texas fields were discovered at points successively farther north along the base of this escarpment.

During 1923 the Cole Petroleum Company drilled three tests near the station of Bruni, Webb County, all of which showed oil and gas. Their No. 4, across the line in Duval County, came in as a large gas well and constituted the discovery well of the Bruni field. Later extensions led to the location of the Cole field, proper. The Henne-Winch-Farris oil field, in Jim Hogg County, was discovered in 1924, and the Randado oil field, in the same county, in 1925.

The location of the fields thus far listed was the result of what might be termed accidental discovery. The position of the original gas fields, on the west side of the main productive area, was initially indicated by shallow gas in water wells. The discovery of oil in the initial well of the Mirando Valley field, located against the Reynosa escarpment, drew attention to the possible structural significance of this topographic feature. This idea led to a trend activity which resulted in the discovery of Schott, Mirando City, and Carolina-Texas and, later, the Mid Ojuelos and Aviators. As far as can be determined, the discovery of both Henne-Winch-Farris and Cole-Bruni resulted from the miscellaneous testing of large blocks of leases.

In the period from 1925 to 1930, geology is credited with the discovery of several additional fields in this general region. The discovery well of the Kohler pool, southwest-central Duval County, located in 1927, was guided by surface fracturing or faulting. Similar evidence led to the discovery well of the Vacuum-S. R. C.-Duval Ranch Company No. 1, northwest Duval County, in the summer of 1930. During this 4-year period the Driscoll gas field (1928), situated east of the Cole-Bruni field in southern Duval County, was discovered by means of a well located to take advantage of a large block of leases. The Government Wells (Schoolfield-O'Byrne) field (1928), in northwest Duval County, and the Escobas (Muckelroy) and Cuellar fields, adjacent to the Jennings gas field in Zapata County, resulted from continued prospecting in areas of oil and gas showings.

STRATIGRAPHY

The geological formations represented within the region range in age from Cretaceous to Tertiary. The line of contact between the Cretaceous and Tertiary is approximately parallel with the coast, and the successively younger formations dip coastward, occupying bands of exposure which strike N. 50° E. in the northeastern part of the region and farther south strike north and south, due to the influence of the major structural trough of the Rio Grande embayment.

In the part of the Coastal Plain with which this paper is concerned, all the surface rocks are Tertiary in age. They may more particularly be referred to those formations of Claiborne age or younger, as the Wilcox is last exposed much farther west and is encountered only in the deepest wells. The Pliocene Reynosa formation overlaps the Oakville throughout the region, and is in turn overlapped by younger rocks, coastward.

The discussion of stratigraphy in this paper deals with the surface and subsurface rocks, with but brief treatment of the former. The reports by Trowbridge[1] and Deussen[2] were used as a reference to supplement the personal field observations of the writer on the distribution and character of the surface sediments. Deussen describes the region as far south as Nueces River, and Trowbridge continues the discussion to the Rio Grande.

In mapping the areal stratigraphy, many difficulties are encountered, resulting in inaccuracies of interpretation. The rocks of Eocene age,

[1] A. C. Trowbridge, "A Geological Reconnaissance of the Gulf Coastal Plain of Texas near the Rio Grande," *U. S. Geol. Survey Prof. Paper 131D* (1922).

[2] Alexander Deussen, "Geology of the Coastal Plain of Texas West of the Brazos River," *U. S. Geol. Survey Prof. Paper 126* (1924).

within the embayment region, have a strikingly similar lithology and, with the paucity of primary exposures and the overlap of re-worked materials and terrace gravels, positive determinations are in many places impossible. The geologist who is now working in the area, with access to the subsurface data made available by well drilling, is forced to question the accepted surface position of many of the contacts, especially those which delimit the Yegua, Fayette, and Frio formations. Unfortunately, available information is insufficient to permit certain correction of such discrepancies.

In the discussion of subsurface stratigraphy which follows, formational classifications are based primarily on micropaleontologic evidence. Such evidence, however, is essentially controversial in character and the age of those strata which border formational contacts is questionable. To treat, individually, the divergent opinions of the different paleontologic authorities would make this paper unnecessarily cumbersome and would serve no useful purpose.

Wilcox group.—The Wilcox is described briefly here because sediments of this age have been partly identified in four deep tests drilled within the area. At the surface, this formation, made up of the basal Indio and the overlying Carrizo sandstone, consists mainly of interbedded sands, sandstones, and shales, the sands composing the greater part of the section. The estimated thickness ranges from 750 to 1,200 feet. The subsurface section, as logged in the four deep tests, is as follows.

The Empire-Sanchez No. 1, Porcion 69, Starr County, was drilled to 3,215 feet and the last 500 feet was identified, on rather meager paleontologic evidence, as Wilcox. This section embraces 100 feet of sands and sandy shales at the top, underlain by clays and shales. The top sand furnished a gas blowout of considerable volume.

The Milham-Salinas No. 2, Porcion 111, Starr County, was drilled to a depth of 5,228 feet and at 4,400 feet penetrated beds identified as Wilcox. These beds are predominantly sandy in the upper 250 feet, and are underlain by shales and clays. A gas blowout was likewise encountered in the top of the sand series.

In the Texas-Jennings No. 2, Zapata County, the Wilcox was encountered at 3,925 feet and penetrated to 4,625 feet. It consists predominantly of sands and sandstones, with minor amounts of calcareous beds and clay. The top sand member contains gas in small volume, under high pressure.

The A. D. J. Pratt No. 2-B, central Webb County, encountered the approximate top of the Wilcox at 2,100 feet, but furnishes little data on

which to base stratigraphic subdivision. The Wilcox is composed mainly of sand, the sands occurring in beds ranging from 1 to 50 feet in thickness. The remainder of the section is clay and shale, with a few thin calcareous beds. A showing of oil was encountered in the upper sands.

Mount Selman-Cook Mountain.—This series has been penetrated in many wells in this area. The subsurface phase is considered as a unit in this paper because of the difficulty of satisfactorily subdividing the two formations.

At the surface, the basal Mount Selman formation is composed of dark clays which weather buff. The interbedded sandstone lenses are micaceous and glauconitic. The overlying Cook Mountain formation is primarily sandy and, in theory, forms a striking contrast to the underlying Mount Selman and the overlying Yegua. In actuality, the weathered material is such that it is extremely difficult to locate the contacts between the associated formations. The typical sandstones of the Cook Mountain are fine- to coarse-grained, with colors regulated by the ferruginous content. The interbedded clays are yellow to brown. Trowbridge[1] gives the series a thickness ranging from 410 to 1,375 feet.

Where penetrated in the course of drilling, this series has a rather consistent lithology, throughout Webb, Zapata, and Duval counties. It consists of alternating beds of sand, clay, and shale, with boulders. Sand comprises 50 per cent of the section. The sand members, ordinarily lenticular, range from a few feet to 100 feet in thickness, but beds of 10-20 feet are more common. No showings of oil are logged from the section assigned to this series, but gas showings are reported in two wells, one of commercial size. The log of the Texas-Jennings No. 2, Zapata County, shows a gas sand at 3,340 feet, midway in the series, and the Magnolia-Hahl No. 1, Duval County, secured commercial gas at approximately the same horizon.

Yegua formation.—This formation is composed, at the outcrop, of dark selenitic clays, with a few thin interbedded sandstones. Like the underlying Cook Mountain, it weathers to a somewhat characterless sandy clay soil. In the course of drilling, wells penetrate about 400 feet of Yegua strata, composed mainly of dark clays, with a few thin sand and calcareous members. The sands, which differ in thickness and importance from well to well, because of their lenticular form, are thin and broken. In spite of the generally non-sandy lithology, this series furnishes one important producing horizon, the "D" gas zone of the Carolina-Texas field.

[1] *Op. cit.*

Fayette sandstone.—The surface sediments grouped under this heading consist mainly of sands and sandstones and are lithologically similar to the Cook Mountain. The sands are lenticular and show a wide variety of colors and textures. They are abundantly fossiliferous. Interbedded with them are clays and shales and lenses of white volcanic material. Chalky concretions are common and give a distinctive appearance to many of the weathered exposures. In the drilled wells, interbedded sands, clays, and shales, with a maximum thickness of 1,500 feet, have been grouped under this classification. The sands comprise about 40 per cent of the whole and occur as well developed beds ranging from 10 to 50 feet in thickness. Their lenticular character is attested by the lateral changes in thickness and position of sands within closely drilled areas.

The Fayette formation constitutes the most productive series in the region. It includes three important producing sands, and several minor "strays" which are commercially important, locally. These are the "Mirando" sand, occurring approximately 500 feet from the top, the Carolina-Texas "B" zone and "C" zone, occurring 800 feet and 1,300 feet, respectively, below the top. The stray sands include the "A" and the "2,300-foot" zones at Carolina-Texas. The "A" zone lies 350 feet below the top of the Fayette and shows gas in a wide area. The "2,300-foot" sand lies 200 feet below the "B" and is a good commercial gas producer in one small part of the field.

There are other persistent zones of lenticular sands within the Fayette which are nowhere credited with either oil or gas showings. An explanation of this phenomenon is offered in a later part of this paper.

Frio clay.—At the surface, the Frio clay is composed of variegated sandy clays, interbedded with thin sandstones. Re-worked volcanic material, which characterizes the formation, predominates in the upper part in what Bailey[1] has referred to as the Gueydan formation. The underground section of the Frio is logged almost exclusively as clay, with a few interbedded sands of minor development. The most important of these sands, economically, lies at the base and is here designated as the "Cole" zone. It ranges locally from a few feet to 40 feet in thickness. It derives its importance from being the main gas producer in the Cole-Bruni field. Four hundred feet above the "Cole" zone there is a sand member which furnished a small gas production in the Leaseholders pool of northeastern Webb County.

[1]Thomas L. Bailey, "The Gueydan, a New Middle Tertiary Formation from the Southwestern Coastal Plain of Texas," *Texas Univ. Bull. 2465* (1926).

The logged section assigned to the Frio has a maximum thickness of 800 feet. The upper contact is in question because of the difficulty in delimiting the overlying Oakville sandstone.

Oakville sandstone.—This sandstone series crops out in a narrow strip through Duval County and is present in isolated outcrops, against the Reynosa overlap, for a considerable distance southward. It is composed of coarse, loosely cemented, salt-and-pepper sand of undefined thickness.

Reynosa formation.—The Reynosa, of probable Pliocene age, unconformably overlaps the Oakville and forms a bold escarpment which is the most distinctive topographic feature of the region. It is composed of sands, gravels, and limestones, interbedded with small amounts of clay. The coarser materials are in most places cemented into a resistant form through action of calcium carbonate. This secondary calcareous deposit, locally known as "caliche," occurs in a bedded form as limestone, or with included pebbles and boulders. Because of the peculiarities of its deposition, the formation shows an irregularity of bedding which is in many places deceptively impressive.

PRODUCING HORIZONS

In the productive districts of the region under consideration, the deepest wells have penetrated sediments tentatively recognized as Wilcox in age. Along the line of the producing fields, the surface formation in which drilling is begun is of Frio age, or of Frio overlain by different thicknesses of Reynosa and Oakville. The formations penetrated are, in order, Frio, Fayette, Yegua and Cook Mountain-Mount Selman. The stratigraphic definitions used in this paper confine the main productive horizons to a 1,800-foot series of sediments, beginning in the lower Frio and extending down into the Yegua. These main horizons, in their order downward in the section, have been designated the "Cole," "Mirando," "B," "C," and "D" zones.

The relations between the several horizons is shown, by cross sections, to be approximately exact, with only slight variation in interval. For example, an interval of 840 feet established between the "Cole" sand and the "B" zone, is found to be constant within all of the fields of the central group. It seems to increase in northern Duval County to about 1,000 feet and decreases in the opposite direction toward Randado to about 800 feet. The interval between the "Mirando" sand and the "B" zone is 280 feet and remains constant wherever these two sands are encountered in the same well.

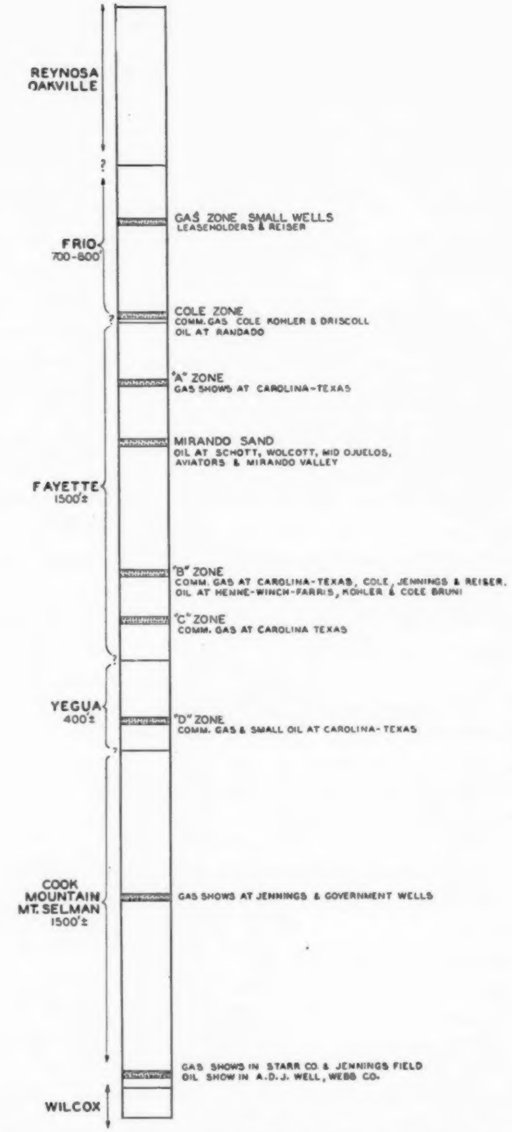


FIG. 1.—Columnar section, Mirando district, showing stratigraphic subdivisions, position of pay sands, and areas in which each sand is productive. Thickness of formations shown in feet.

The productive quality of each zone varies with the areas in which it is located, because of the influence of lenticularity and differences in porosity. It is probable that each of the important sand zones is present as a stratigraphic unit throughout the region, but local lithologic changes add to or detract from its suitability as a reservoir.

Carolina-Texas.—In the Carolina-Texas gas field there are three main productive sands, one stray producer and two sandy zones that make showings in some wells. They are here tabulated.

	Depth in Feet
"Cole" sand. Showings	1,250
"A" zone. Sand or sandy shale. Non-commercial	1,550
"B" zone. This is the main gas horizon and productive on the crest of the dome and on the north, northwest, and west flanks. It is replaced by sandy shale on the southeast flank	2,100
"2,300-foot" stray. A good producer in small spots	2,300
"C" zone. The productive phases of this zone occur in Survey 684, on the southeast flank, and in one well on the west flank. It has furnished several small oil wells	2,600
"D" zone. This zone produces large gas wells locally. Ordinarily missing or non-productive	3,050

In the area east of Carolina-Texas, most of the productive horizons of this field are represented as sandy zones. The 1,800-foot sand producing gas, from the Simms-Dinn No. 1, northward throughout the Kohler region, is the equivalent of the "Cole" sand. The 2,800-foot oil and gas horizon in the Kohler field is the equivalent of the "B" zone.

Schott, Mid Ojuelos, Aviators, and Mirando Valley fields.—The main oil production of this group of fields is derived from the "Mirando" sand, which lies at depths ranging from 1,500 to 1,650 feet. The oil has a gravity of 21°-22° Bé. The only other commercial sand within this group occurs at Schott, where the "B" zone is productive in a limited area, at a depth of 1,900 feet. The oil has a gravity of 45° Bé.

Henne-Winch-Farris.—The oil and gas in this field are obtained from the "B" zone, encountered at depths ranging from 1,950 to 2,100 feet. The gravity of the oil is 21°-22° Bé. The productive zone ranges in thickness from a few feet to 50 feet.

Randado.—The main production at Randado is obtained from a sand which occurs between 1,270 and 1,299 feet. It is of lower Frio age and the approximate equivalent of the "Cole" zone. The interval to the "B" zone is 800 feet. The gravity of the oil is 21°-22° Bé.

Jennings area.—In the Jennings area there are four fields. These include the Jennings gas field proper, the Escobas (Muckelroy) oil field, known as South Jennings, the Cuellar field, known as North Jennings, and the Martinez field, known as East Jennings.

In the Jennings gas field there are three main gas horizons. The 1,210-foot sand is the equivalent of the "Mirando" sand, the 1,450-foot sand is the approximate equivalent of the "B" zone, and the 1,950-foot sand is the approximate equivalent of the "C" zone.

The Cuellar field at 1,500 feet and the Escobas field at 1,250 feet are producing from the "B" zone.

Cole-Bruni.—This gas area is producing from two main horizons: the "Cole" sand, encountered at 1,700 feet, and the "B" zone, at a depth of 2,340 feet. The latter zone produces gas in an area west of the main field, between Cole and Carolina-Texas. It also produces gas south of the town of Bruni and furnishes a small amount of 21°-22°Bé. gravity oil in a group of wells west of the main pool. The "Cole" sand is the main source of gas production and furnishes large wells in the entire field. This sand also produces heavy oil in minor amounts.

Within the Cole pool and in the adjacent area, the lower recognized horizons of the Carolina-Texas field are present as sandy zones, but without commercial importance. A well within the field, Cole-Benavides No. 36, Survey 412, Block 14, was drilled to a depth of 5,150 feet. A good showing of oil was developed in the "B" zone at 2,325 feet, but below that depth no showings of oil or gas are reported. This test logs sandy shale at the "C" zone (2,825-2,880 feet) and a good sand at the "D" zone (3,400-3,480 feet). From 3,500 to 4,000 feet sand conditions are excellent, but from this depth to the bottom of the hole, no sands are logged. The well was abandoned in strata of probable middle Claiborne age.

Miscellaneous fields.—In the Reiser gas field, many wells have been junked, flooding all sands with gas and water. It is, therefore, impossible to correlate any of the producing sands with certainty. What accurate data are obtainable indicate that the 600-foot horizon is to be correlated with the "B" zone and this designation has been used in this paper.

The Government Wells field (Schoolfield-O'Byrne) is producing commercial oil from the "B" zone at approximately 2,300 feet. The recently completed well of the Vacuum-S. R. C. Companies in northwestern Duval County is producing 21° Bé. gravity oil at 1,730 feet, here tentatively classed as the "B" zone.

In the Driscoll field, 10 miles northeast of Cole-Bruni, there are two producing sands that yield large quantities of gas, with minor amounts of oil. These are the 2,400-foot sand, here correlated with the "Cole" sand, and the 2,900-foot horizon, the seeming equivalent of the "Mirando" sand.

STRUCTURE

The regional structure of the Tertiary rocks of the western part of the Gulf Coastal Plain is mainly the result of depositional conditions. There is no evidence at the surface or in the subsurface of any major movement that may have radically deflected these sediments away from their original attitude. The Coastal Plain, in this area, is a gentle monocline, in which the regional dip changes from southeast in the northern part, to east and northeast in the southern part. This change is the result of the re-entrant of the sedimentary contacts into the shallow remnant of the major trough of the Rio Grande embayment.

SURFACE STRUCTURE

The lithologic character of the surface sediments of this region renders them unfit for structural interpretation. Cross-bedding and lenticularity tend to destroy the value of the individual outcrop as a structural index, and the repetition of lithologic types and indiscriminate overlapping of re-worked materials, hopelessly confuses the local trend of formational contacts which ordinarily constitutes the most significant indication of structural abnormality.

The minor structural terrace, the most typical of local structural types, is not such as would be expected to find expression at the surface. There is evidence that fracturing is common throughout the region, but the undisturbed nature of the beds closely associated with such zones indicates that their influence is mainly confined to the surface beds.

SUBSURFACE STRUCTURE

To accompany this paper, a subsurface map has been constructed, representing an area about 85 miles long and 40 miles wide, including the productive areas and adjacent territory. Under the discussion of stratigraphy, it has been pointed out that the Eocene sediments which comprise the surface rocks are, because of their method of deposition, characterized by lenticularity, with rapid interchange of lithologic types. Certain sandy phases of the section are continuous, as lithologic units, in broad areas, but because of their similarity to many other sandy phases, they can not be used as a contour datum, except under special conditions. Such limitations, therefore, render it impossible to extend subsurface contour mapping to any great distance from the producing fields. Within the fields, certain horizons are productive and are known to occur at regular intervals in the section. On the margins of the fields and in inter-field territory, they may also be recognized by their oil and gas

showings and by the established intervals which separate them. It is obvious, however, that with greater distance from proved territory, the wider spacing of wells increases the chance for errors in correlation. Detail contouring, therefore, is practicable only in that territory where correlations may be extended with a fair degree of certainty.

The map accompanying this paper is a composite of several field maps, each contoured on the main local sand, with a 10-foot contour interval. As an example, Schott, Aviators, and Mirando Valley were contoured on the "Mirando" sand; Henne-Winch-Farris, Jennings, Reiser, and Carolina-Texas on the "B" zone; Cole-Bruni and Randado on the "Cole" sand, and so on. After consolidation of all fields, the "B" zone was used as datum, because of its more widespread occurrence. Definite reduction intervals were established by means of cross sections. The composite map is contoured on a 50-foot interval and presents the structural features of the entire area in simplified form.

The structure of the region as a whole is that of a monocline, with considerable regularity in the rate of coastward dip. From northeast to southwest and south, along the strike, the contours swing in gentle undulations, forming flat, gently plunging folds. There is no regularity in the arrangement of these minor structural features and little significant relationship between them and the productive areas. Within the territory, the Carolina-Texas dome is the most pronounced structural feature. Cutting the northwest flank of this dome, a northeast-southwest fault is hypothesized, downthrown toward the northwest approximately 250 feet. This interpretation finds a basis in the uncertain correlation of three well logs. There is no known surface evidence to substantiate the presence of either dome or fault.

In the area between Torrecillas and Mirando Valley, on the north-south line occupied by the Schott, Mid Ojuelos, and Aviators fields, there is an increase in the rate of eastward monoclinal dip, from 100 feet to the mile to 150 feet. This increased dip affects an area about 4 miles wide from east to west and the terrace thus formed may be the cause, in part, for the accumulation of oil along this line. Toward the east, between this terrace and the Cole-Bruni field, the dip decreases to less than 50 feet to the mile, but again increases to normal from Cole, eastward. This pronounced flattening is not to be noticed north or south of this particular area.

The Henne-Winch-Farris field, productive from a horizon 280 feet lower than Schott, is also located on a slight terrace. This terrace is southeast of the other, but approximately parallels it.

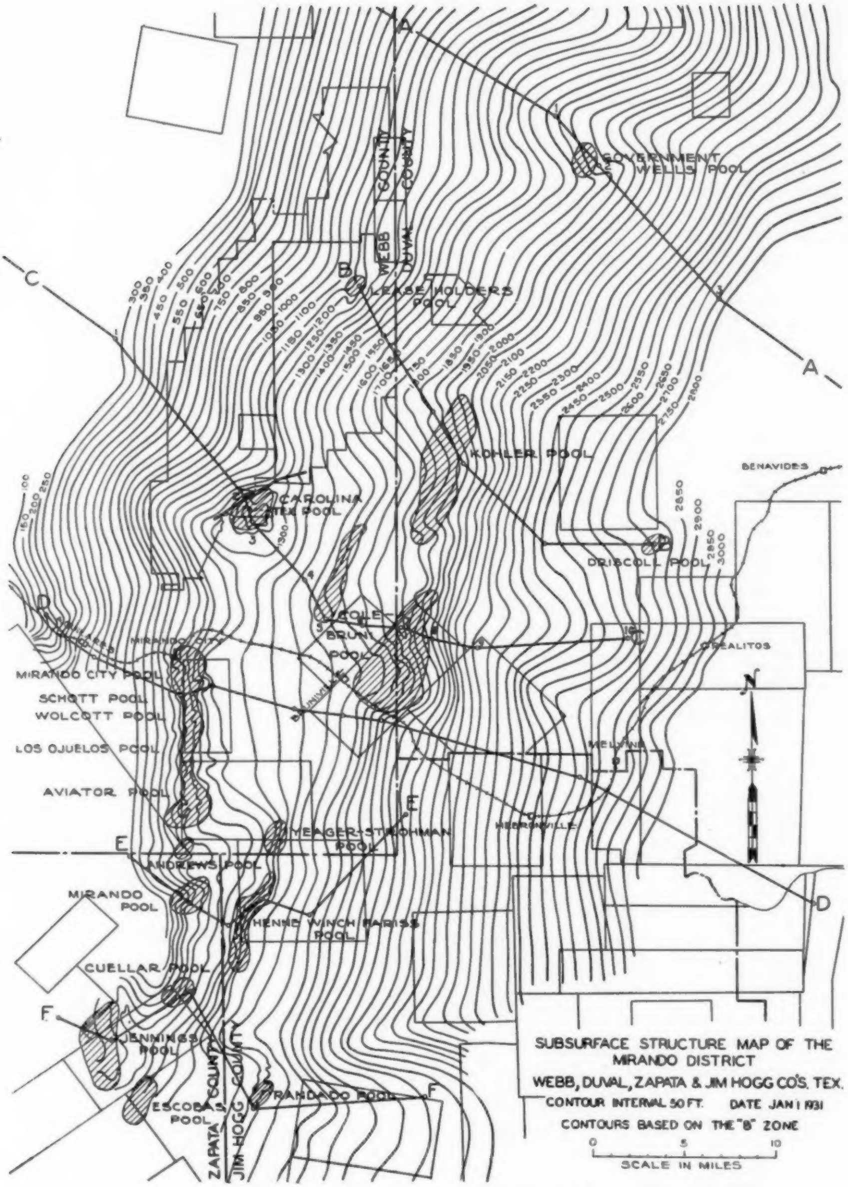


FIG. 2.—Subsurface structure map of Mirando district, contoured on "B" zone as datum.

Geologic section *A-A* is shown in Figure 4: *1*, Magnolia Petroleum Company's Hahl No. 1; *2*, H. B. Schlesinger's Moody No. 3; *3*, Maurer and Duggan's Roffman No. 1.

Geologic section *C-C* is shown in Figure 3: *1*, Arkansas Natural's Feldman No. 1; *2*, Morgan Gibble's Garza No. 1; *3*, Carolina-Texas' Benavides No. 1; *4*, National Oil's Benavides No. 2; *5*, Cole Petroleum's Benavides No. 36; *6*, Cole Petroleum's Benavides No. 50; *7*, Killam Rosa's Benavides No. 8; *8*, Cole Petroleum's Benavides No. 25; *9*, Moody-Seagraves' Benavides No. 1; *10*, Hoffer-Smith's King No. 1.

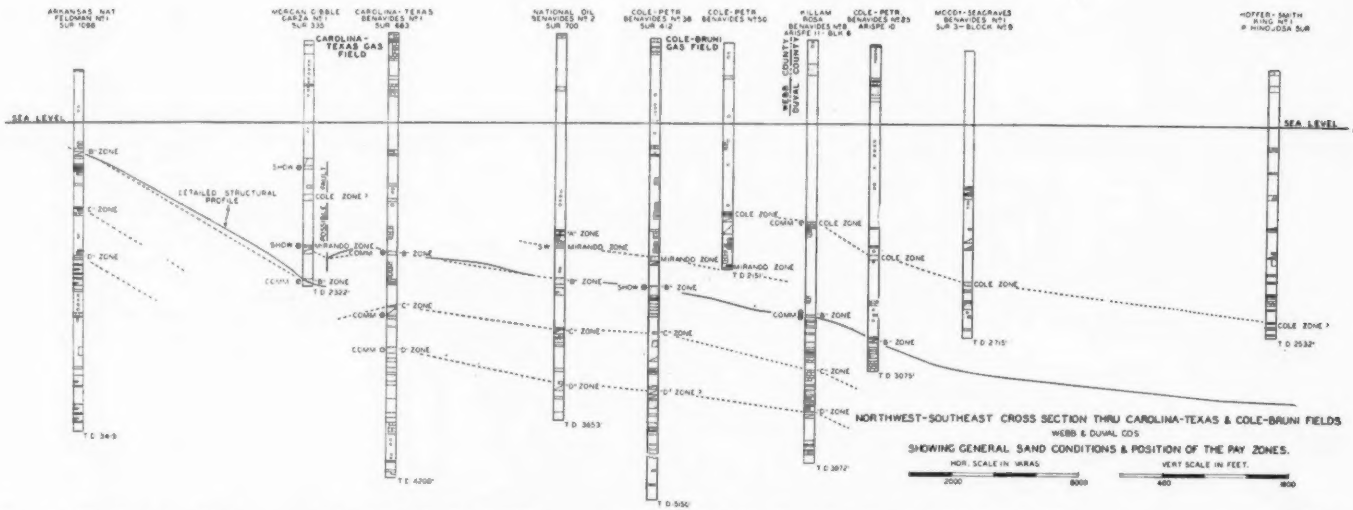


FIG. 3.—Northwest-southeast cross section through Carolina-Texas and Cole-Bruni fields. (Location shown by line *C-C* on Figure 2.) 2,000 varas = 5,500 feet.

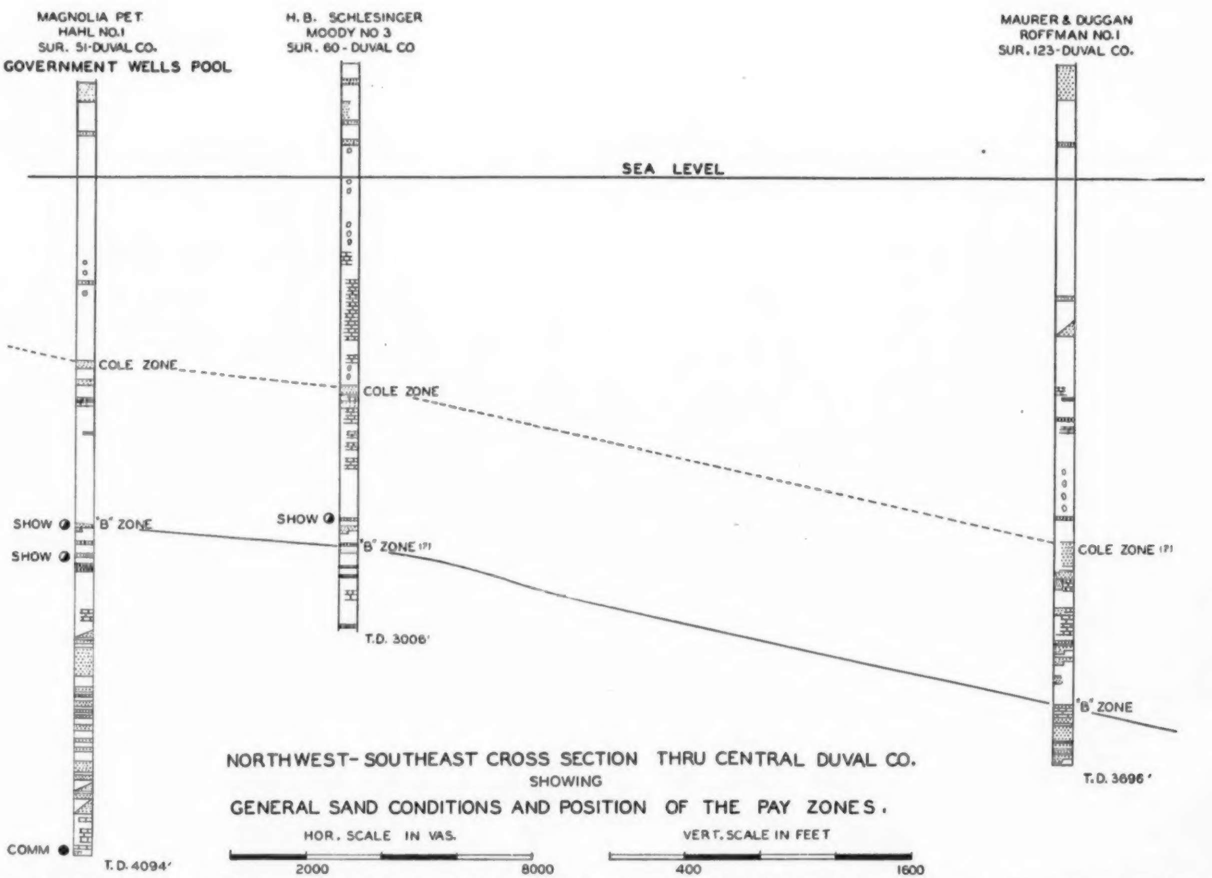


FIG. 4.—Northwest-southeast cross section through central Duval County. (Location shown by line *A-A* on Figure 2.) 2,000 varas = 5,500 feet.

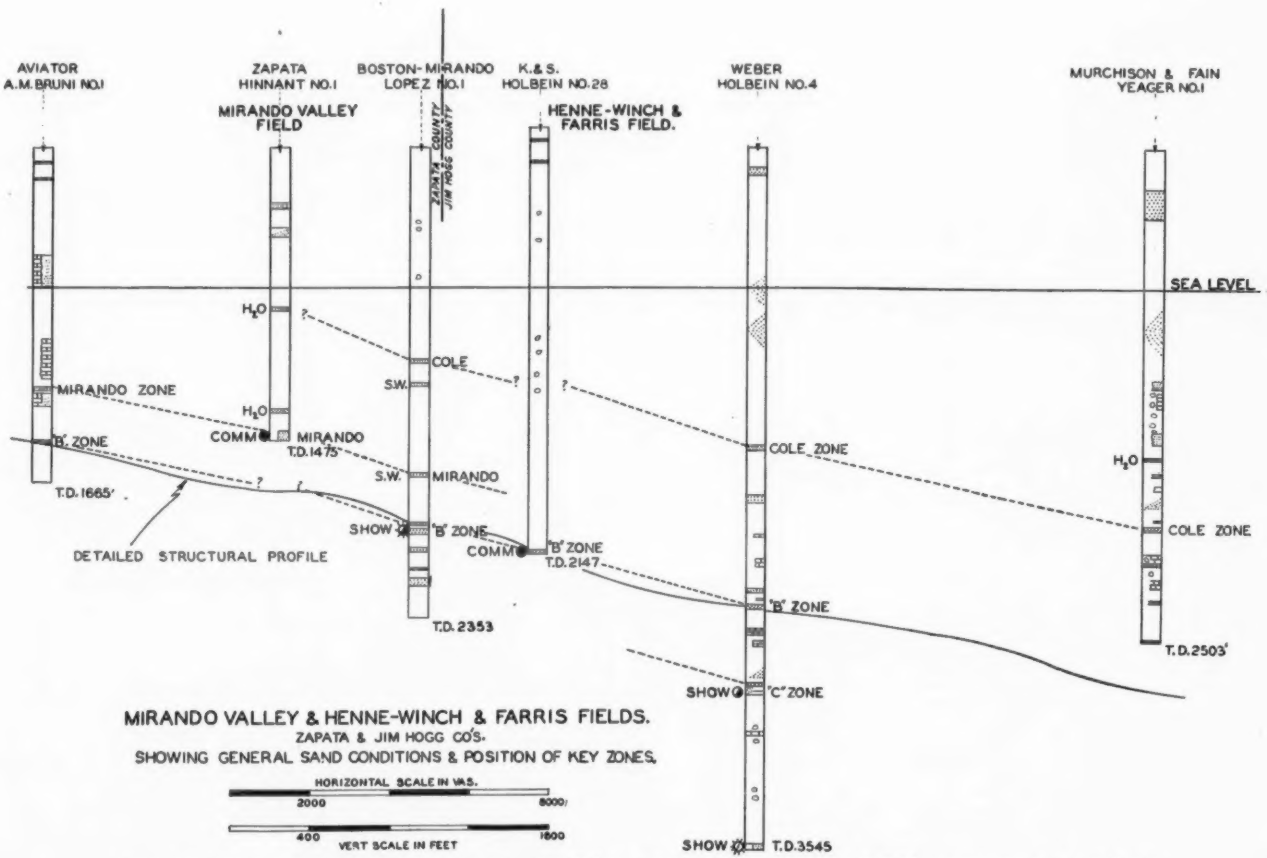


FIG. 5.—East-west cross section through Mirando Valley and Henne-Winch and Farris fields. 2,000 varas = 5,500 feet.

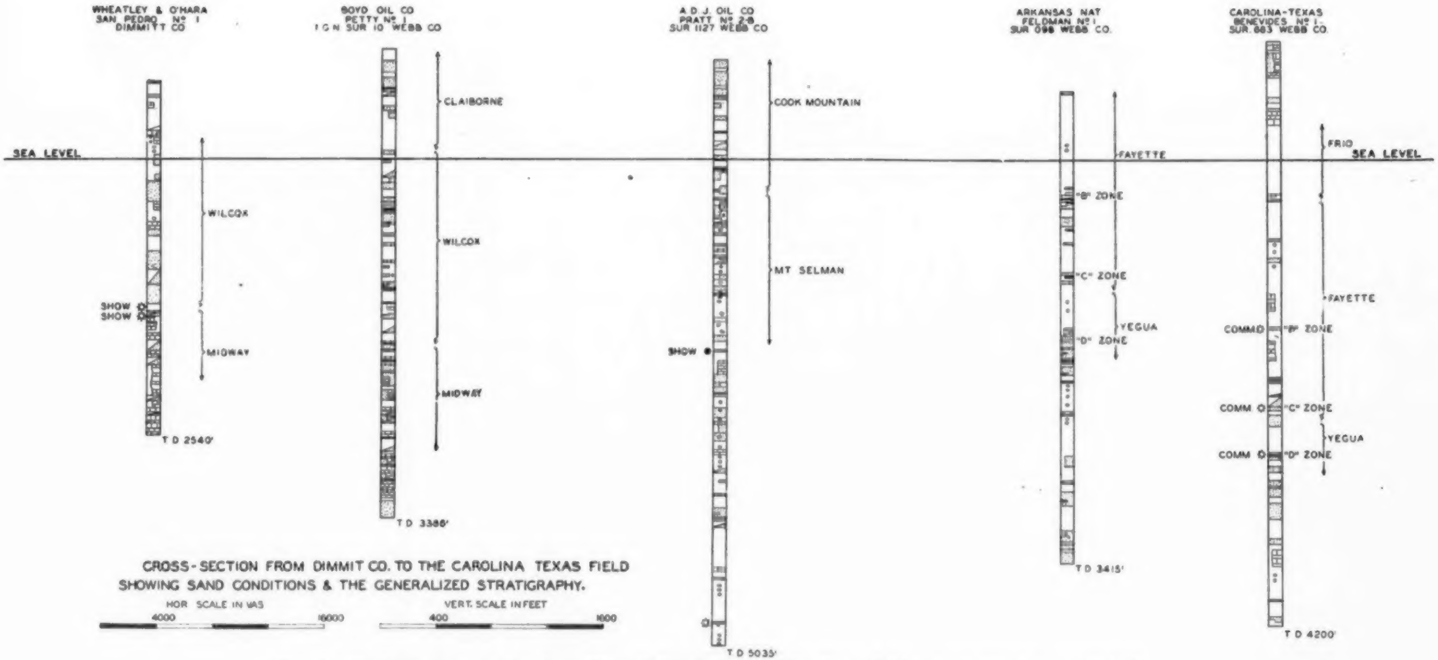


FIG. 6.—East-west cross section from Dimmit County to Carolina-Texas field. 4,000 varas = 11,000 feet.

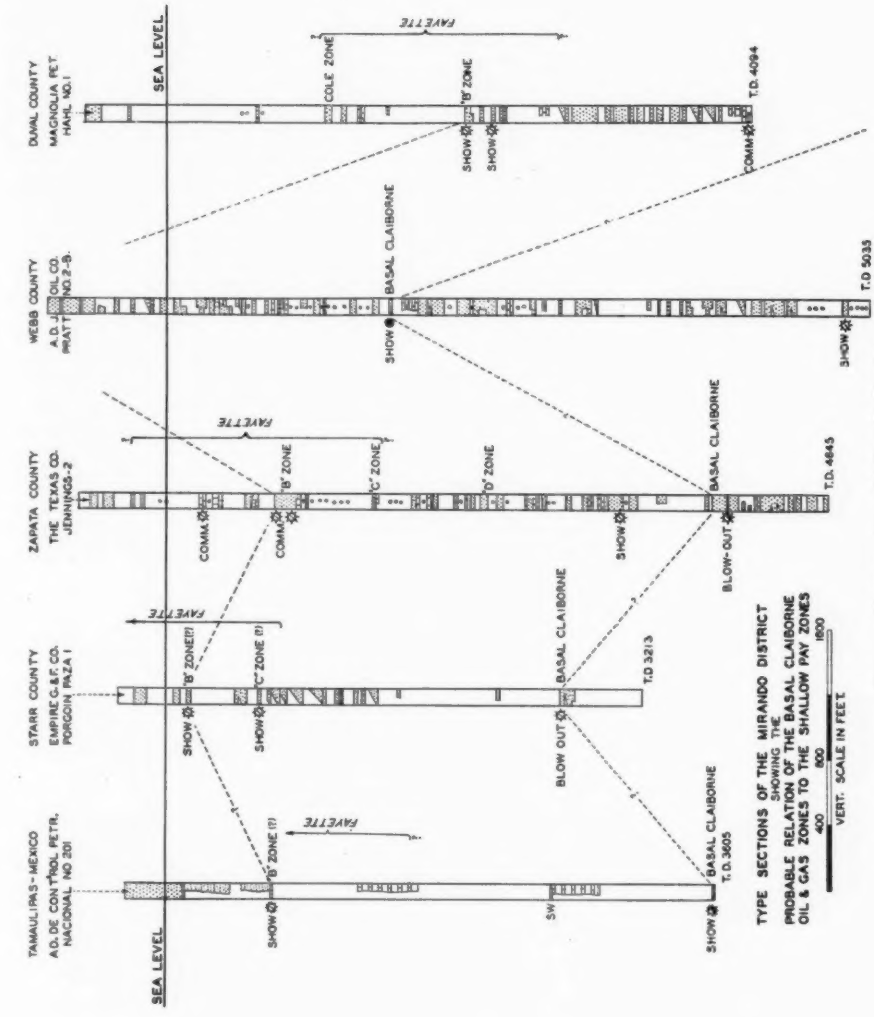


FIG. 7.—Type sections of Mirando district.

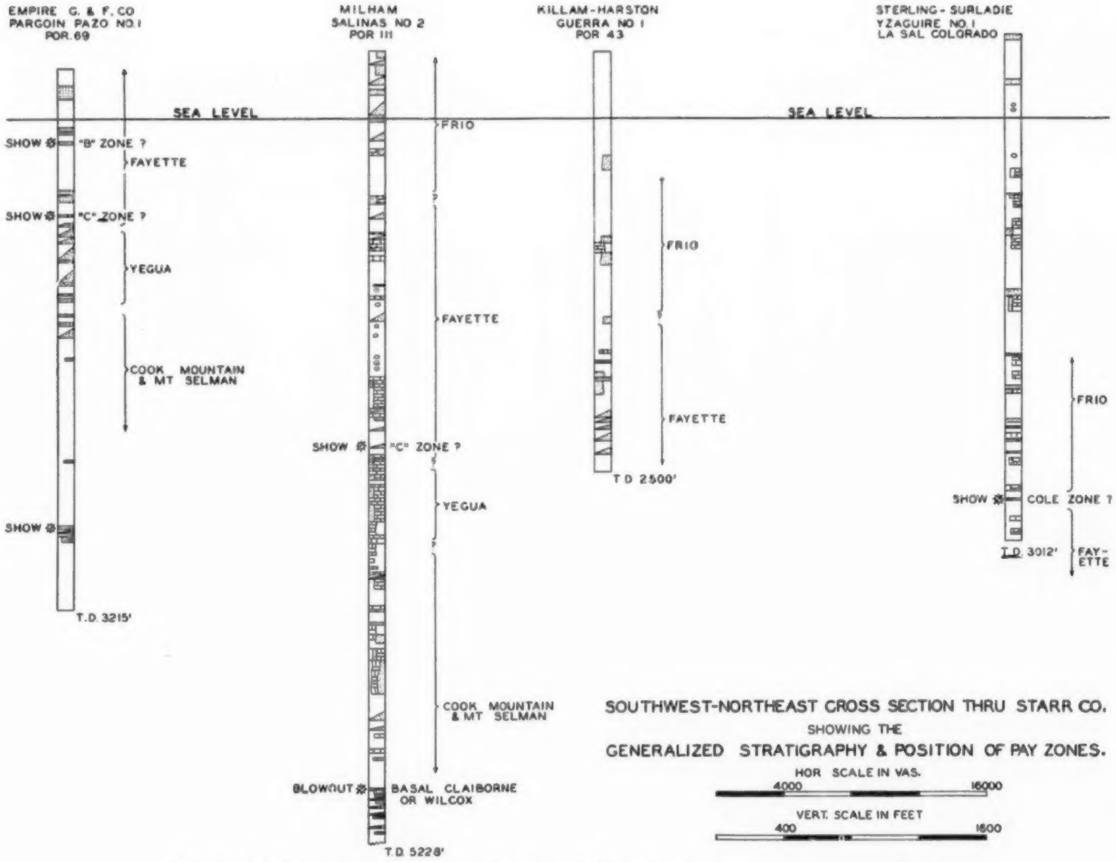


FIG. 8.—Southwest-northeast cross section through Starr County. 4,000 varas = 11,000 feet.

Within the productive areas of the Cole-Bruni, Jennings, and Randado fields, mapping on a 10-foot interval produces evidence of considerable warping of a minor type. At Cole, the warping is exceedingly irregular, but with general east-west axis. Oil and gas are produced in wide areas, irrespective of structural irregularity. At Randado and Jennings, the upper surface of the producing sand shows an irregularity which, if structural, has had little influence on the distribution of oil and gas. The narrow, plunging "folds" in the latter field may be the product of miscorrelation between the several sands.

On the larger-scale maps, the 10-foot contour interval and the many control points show many sand irregularities in the area of production. These are small domes, closed synclines, sharp folds, and synclines, none of which embraces an area of more than 40 acres. It is impossible to classify such minute warpings as products of structural deformation, although it is conceivable that some may have resulted from compacting. Most of them may be explained more readily as having resulted from the inequalities of shore-line deposition.

Besides such minor features which accompany the commercial occurrence of oil and gas, there are several pronounced irregularities which may or may not be significant. One of these is a well defined eastward bulge of the contours east of the Randado field, in western Jim Hogg County. The structural interpretation is here based on the logs of several wells north and east of Randado, in which the correlation of sands is very difficult. A second interesting area lies immediately east of the north end of the Carolina-Texas field. The contours are here deflected toward the east to form a flat, eastward-plunging fold, with a width of about 10 miles. This warp is made significant by the extension of the Kohler field across its width.

Three other areas of contour irregularity occur in Duval County. One of these extends slightly south of east from the north end of the Cole field, for a distance of about 10 miles. The Driscoll gas field occupies a minor warp branching off northeastward. The second area lies east and west across the north-central part of Duval County. The Government Wells pool occupies the eastern part of this area. The third and most prominent area extends from the northwest corner of Duval County, southeastward toward the town of San Diego. The wells drilled throughout this area have offered many fine showings of oil and gas in the recognized sands, and the recently completed oil well of the Vacuum-S. R. C. Companies is on the northwest edge.

FRACTURING AND FAULTING

Evidence of faulting within the area has been observed in several places, but its exact function in controlling the accumulation of oil is imperfectly understood. The most notable fault cuts the northwest flank of the Carolina-Texas field. Although there is possibility of error in the correlation of well data on which this interpretation is based, the presence of oil and gas in normally barren sands indicates that a channel has been provided for vertical migration. Excepting this one example, detailed subsurface study has furnished no positive evidence to suggest that fault displacement has controlled commercial accumulation of oil and gas.

On the surface, there are indications of fracturing west of the Kohler field and northwest of the Vacuum-S. R. C. discovery well, Duval County. In each of these places, the surface evidence consists of a northeast-southwest zone of steeply dipping beds, intermittently exposed. There is some indication of secondary alteration. From these exposures it is impossible to ascertain whether displacement has occurred, but the undisturbed position of the beds adjacent to the fracture zone indicates that movement has been of minor quantity. Without major displacement and consequent warping of the producing horizon, such fracturing would perform the same function as lenticularity in the formation of a trap. At Kohler, the spotted manner in which accumulation has occurred in wide areas offers many difficulties in sand recognition. It is possible, with one group of correlations, to hypothesize a zone of northeast-southwest faulting, consisting of a normal fault of considerable throw, backed by a downthrown block. Conditions here, however, may more readily be explained as having resulted from lensing within the two producing horizons.

Additional evidence of fracturing has been observed in Starr, Webb, and Duval counties, consisting of veins and knobs of chalcedony and opal, local steepening of the dip in isolated outcrops, and local changes of mineral content in surface waters. The writer considers such manifestations to be surficial in influence and to have little bearing on the local control of oil and gas accumulations.

FACTORS CONTROLLING ACCUMULATION

In the preceding discussion, it has been demonstrated that the sandy members which act as reservoirs for the oil and gas of the region are widely distributed as definite zones, separated from one another by somewhat constant intervals. The pure sand phases that occupy these zones

are lenticular, with gradations within short distances from pure sand to sandy shale in which sand predominates and to sandy shale in which sand is a minor constituent. This is illustrated in the Carolina-Texas field where the "B" zone is productive in part of the field, and grades out into a non-porous medium in other parts.

The sediments that compose the Eocene section of this region were deposited under shore-line conditions, where rapid advances and retreats of the sea and strong and irregular cross currents resulted in the continual re-working of materials in the processes of deposition. This has resulted in the formation of many long, narrow bars, paralleling the shore line, but lensing within short distances into sandy shales or shales, both laterally and seaward. In the group of fields, from Mirando City to Aviators, these depositional features are well illustrated in the development of the "Mirando" sand. The open, porous phases of the sand are productive of oil along a narrow zone, paralleling the strike of the beds. On the inshore side, the pore space is gradually reduced and the sand becomes gas bearing. Though the lensing of the sand on the up-dip side of the sand body in many places permits the separation of oil and gas through gravity segregation, there are gas areas within the oil zone where there is complete absence of structural differences to account for the segregation of these products. This is strikingly illustrated in the Henne-Winch-Farris field. At the northern end, the oil zone is bordered on the west (up-dip) side by a gas zone of equal width. Southward along the strike of the field, under identical structural conditions, the area west of the oil is entirely barren. This relationship is only to be explained by a lateral gradation in porosity within the reservoir rock.

With so many local examples of the function of differences in porosity in the control of oil and gas accumulation, it is evident that this factor is primarily the cause for the trapping of these deposits in this region. Excepting the Carolina-Texas dome, the only structures of the area are of the terrace and "nose" type and, though they may have exerted a partial influence, the irregularity of accumulation with respect to them shows that their influence has not been great.

SOURCE MATERIAL

A consideration of gradational porosity as a factor in oil and gas accumulation advances another factor of equal importance. It has been pointed out that the few sand zones that are productive are widespread in their occurrence. The "Cole" zone is productive both in the Cole field and in the Randado field, 40 miles distant. In the area intervening,

the Henne-Winch-Farris field is productive from the "B" zone. The "Cole" zone in this area contains a thin sand, but it yields no more than an occasional showing of gas. Throughout the region there are other sand zones, closely associated in the section with the "Cole," that contain no oil or gas, regardless of structural conditions. Also, the "B" zone is productive in a small area in the Schott field, 280 feet below the main producer. In the fields extending toward the south, this zone contains in many places a well developed sand, but it is non-productive. Still farther south, the "B" zone is productive as the main gas "pay" of the Jennings field. Associated with the "B" zone in this strip of territory are other more or less persistent sands which are not productive under any circumstances yet encountered.

The explanation of this frequently repeated phenomenon is to be found in the position of the source beds relative to the reservoir beds. The data so far presented indicate that source material, from which oil and gas at any horizon are derived, was originally contained within that sand zone or in the adjacent sediments. In the processes of deposition, the conditions necessary to the formation and preservation of source material were periodically favorable in wide areas, resulting in accumulation at definite horizons. The sands deposited contemporaneously with the source material have become the producing horizons of to-day. This theory explains why commercial production, regardless of geographical location within the region, is confined to one sand or more belonging to a recognized group of sand zones. Inversely, sands, however persistent, not belonging to this group, that is, not associated with source material, are nowhere productive. The presence of deep-seated faulting, as at Carolina-Texas, may alter this last statement.

PETTUS AREA, BEE COUNTY

It is the expressed purpose of the writer to analyze the factors controlling the accumulation of oil and gas in the Mirando district, in order that this knowledge may be used in the appraisal of areas outside this immediate district. A consideration of the application of these factors to conditions at Pettus is, therefore, undertaken.

History.—The discovery of this field is the most important development in the later period of exploitation of the inner margin of the Gulf Coastal Plain. It established the heretofore questioned potentiality of the Eocene section in areas situated immediately northeast of the Mirando district. This field furnishes wells of uniformly large initial output and with a rate of decline much less than that which has characterized

Eocene fields of the past. The discovery of this field in 1930 may be attributed indirectly to showings encountered in shallow water wells. Subsequently, two oil areas, Cosden and Grayburg, and several productive gas areas have been located in the territory surrounding Pettus, some of which discoveries are credited to geological research.

Stratigraphy.—The surface of the Bee County area, in which the Pettus group of fields is located, is covered by typical sediments of Reynosa age. Within the Pettus field proper, the section to a depth of 2,500 feet includes the Fleming (Reynosa, Lagarto, and Lapara) group, Oakville sandstone, Gueydan formation, and Frio clay. An exact separation of these members is impractical with our present knowledge and is not essential to this paper.

Below the Frio clay, between this formation and the Yegua, there is approximately 1,500 feet of strata which occupy, in general, the interval of the Fayette sandstone of the Mirando district. On the basis of paleontologic evidence, this group has been divided into four members. At the top is the Fayette with a thickness of 600 feet. The Fayette is underlain successively by the McElroy beds with a thickness of 500 feet, the 100-foot *Dibollensis* zone, and the Cockfield beds, with a thickness of 250 feet.

An analysis of the fossil content of this 1,500-foot section, from Frio to Yegua, indicates that it is only in small part the equivalent of the same interval in the type section of the Mirando district. The Fayette, which at Mirando attains a thickness of 1,500 feet, has been reduced at Pettus to 600 feet, by the removal or non-deposition of the upper members. Inversely, the McElroy, *Dibollensis*, and Cockfield members have been introduced, locally, between the Fayette and Yegua. To clarify this very complex situation, created by paleontologic determination, it will be necessary to consider the outcrop.

In the area northwest of Pettus, the Fayette, Frio, and Oakville formations crop out successively, in parallel bands, from the north line of Karnes County, southward to the town of Kennedy. According to Duessen,[1] the Fayette in this locality has a thickness not exceeding 500 feet and it is immediately overlain by the Frio and underlain by the Yegua. The drastic thinning of the Fayette from the Mirando district, northeastward, may have occurred in the upper members, but the indeterminate character of the micro-fauna in the outcrop does not furnish definite evidence to establish this conclusion. This evidence indicates fairly definitely, however, that the 850-foot section comprising

[1] *Op. cit.*

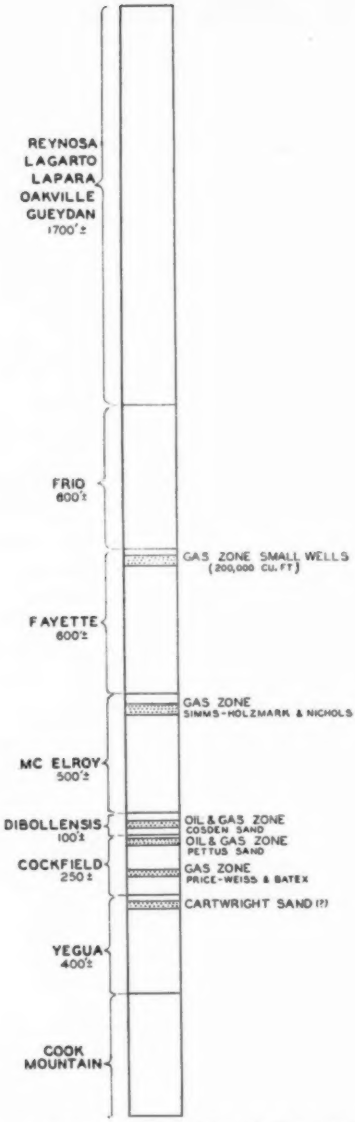


FIG. 9.—Columnar section, Pettus district, showing stratigraphic subdivisions and position of "pay" sands. Thickness of formations shown in feet.

the McElroy-*Dibollensis*-Cockfield group is not present in Karnes County. If determinations are to be based entirely on paleontologic grounds, with a disregard of lithologic evidence, it is necessary to assume that this stratigraphic group represents a depositional wedge which was delimited, shoreward, by a line falling between the Pettus field and the surface outcrop in Karnes County.

In the Pettus area, the productive horizons thus far established are assigned to a group of strata occupying the interval between the basal Frio and the upper Yegua. The writer does not feel qualified to suggest permanent names for these horizons but, as no accepted nomenclature has been adopted, designations here used are for the purposes of this paper, only. There are six distinct producing sands within the region. These sands include the "Ray" horizon, of basal Frio age, which furnishes gas wells of small volume in the area adjoining the Pettus pool on the north; the "Holzmark" sand, occurring in the upper part of the "McElroy" beds, which produces large quantities of wet gas and minor amounts of oil in the Simms-Holzmark wells and in the Nichols wells at Normana; the "Cosden" sand, occurring within the *Dobollensis* zone, producing oil and gas in the Cosden pool immediately west of Pettus; the "Pettus" sand of upper Cockfield age; the "Weiss" sand of middle Cockfield age, producing commercial gas in the Price-Weiss wells on the central Bee-Goliad county line, and the "Cartwright" sand, of upper Yegua age, which constitutes the deep gas "pay" in the Lucas field, Live Oak County.

It is not the purpose of the writer to enter here into a detailed discussion of the relation of production to stratigraphy in the Pettus district. This is a problem for the paleontologist and stratigrapher who has been permitted to specialize on this particular region. The foregoing discussion constitutes a generalization of present knowledge and is presented in order to draw an interesting parallel between this district and Mirando. At Mirando, the main productive sands occur in the 1,800-foot interval between the base of the Frio and the middle of the Yegua. At Pettus, production is limited to the 1,600-foot section lying between the Frio-Fayette contact and the upper part of the Yegua. The two sections, therefore, lie between the same stratigraphic limits and are, from the standpoint of lithology, identical. Paleontologically, however, age equivalence between the two sections is confined to an approximate 600-foot interval of basal Fayette strata.

The problem presented by these anomalies is one in which there is little common ground between the lithologist and the paleontologist.

A situation exists in which, at Pettus, there has presumably been introduced into the stratigraphic section a wedge of sediments with a thickness of 850 feet. This wedge consists of materials of almost identical lithology with the lower 900 feet of the Mirando Fayette. However, the 900-foot section of the Mirando Fayette is absent, so that, based on paleontologic age determinations, the two areas, within this interval, have but one stratigraphic segment in common, the basal 600 feet of the Fayette. It is admitted that it lies outside the capabilities of this writer to establish or refute the truth of these conclusions and his purposes have been served by the brief treatment that has been accorded this problem.

Structure.—In that part of Bee County in which production of oil and gas has been established, the overlap of materials of Reynosa age has tended to obscure all those features which might be used in an attempt at structural interpretation. Many zones of fracture have been located, along which alteration of sediments has occurred. These zones have no local uniformity of strike and have been observed with trends both northeast-southwest and northwest-southeast.

The problem of subsurface structural interpretation is complicated by the impossibility of choosing a suitable datum for widespread mapping, because of the present imperfect knowledge of the section. The six recognized producing sands of the area occupy a thick section of strata and insufficient drilling has been done to permit the construction of cross sections by means of which definite intervals might be established between these sands. The generalities of subsurface structural conditions may be outlined by contouring on a paleontologic and lithologic break locally termed the top of the Jackson, a horizon 1,100 feet above the "Pettus" sand. For detailed mapping, the variation in this interval destroys its value as a structural index, and the geologist is forced to confine his efforts to local areas in which productive sands are to be recognized with certainty, with no attempt to reduce these areas to a common base.

In the area adjacent to the Pettus field, the regional contours, based on the "Pettus" sand, show an irregular monocline, striking N. 50° E. and dipping coastward at the rate of 100 feet to the mile. This rate of dip continues from the north Bee County line, southeastward to the north edge of the Pettus gas area, but increases southward through the productive area to about 200 feet to the mile. In the Pettus field proper, the abundant control shows the upper surface of the productive sand to be warped into minor plunging folds, with axes at right angles to the

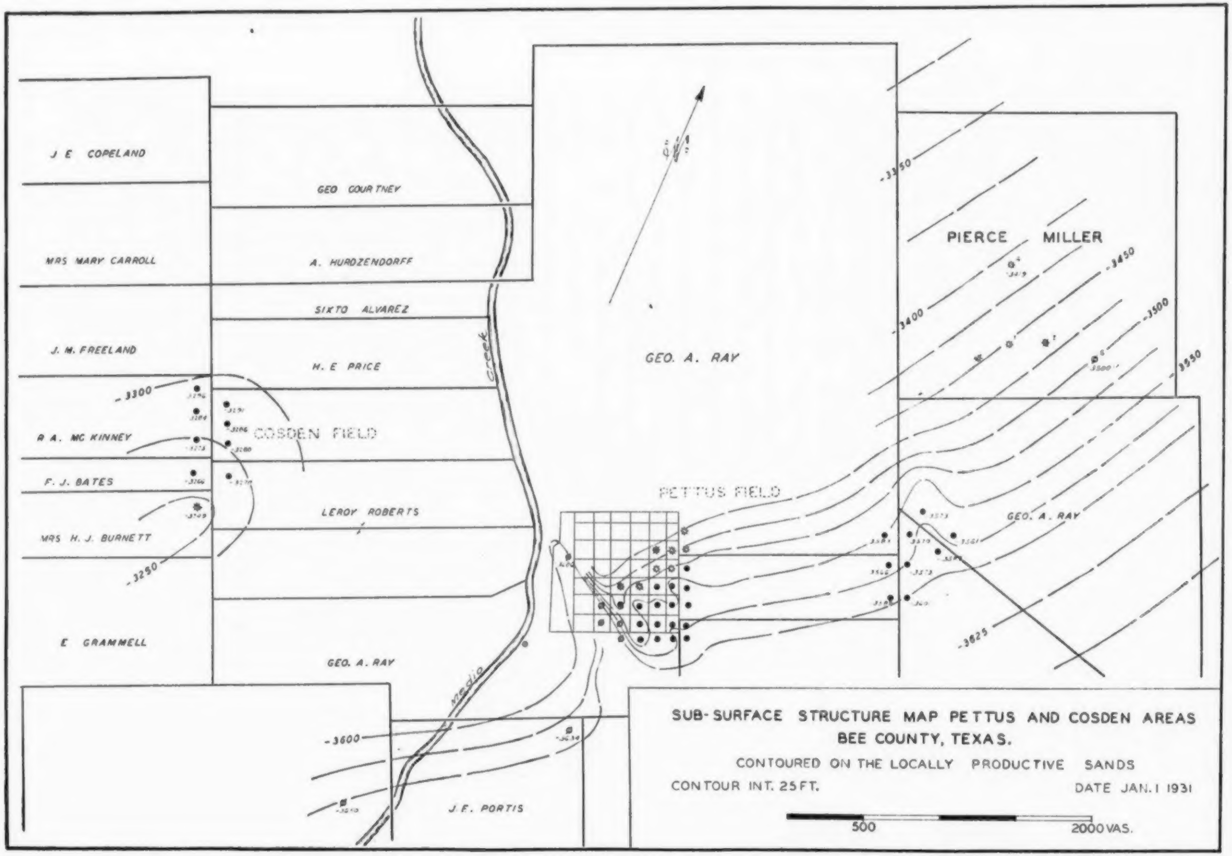


FIG. 10.—Subsurface structure map of Pettus district, showing Pettus and Cosden fields, contoured on local producing sands. 500 varas = 1,375 feet.

strike. On the northwest side of the productive area, the control indicates that the sand zone continues its normal rise, without break or reversal. The northeast end of the field, along the strike, has not been defined by drilling, and the condition that will terminate production in this direction can only be imagined. On the southwest end the producing sand, which occupies a normal position in Blocks 20 and 23, Pettus townsite, abruptly ends in Blocks 9 and 21, giving the appearance of faulting. This change is here attributed entirely to lithologic gradation, caused by channel cutting subsequent to sand deposition, and it is believed that the sand will be encountered farther southwest. This theory is substantiated by the presence of the "Pettus" sand in a normal position in the Houston-Portis No. 1 and the Morgan-Ray No. 1, west and southwest of this northwest-southeast barren zone.

Accumulation in the Pettus field occurs in a long, narrow zone, on the terrace formed by the change in rate of the coastward monoclinal dip. As in the fields of the Mirando district, the gas occupies a strip on the upper margin of the field, and is succeeded down-dip by an oil strip of more or less equal width. The dividing line between the oil and gas is sharp. Within the pay horizon there is a clearly marked gradation in the porosity of the sand. In the gas area, the sand is very fine, grading down-dip into a coarser sand that contains the oil. Within the oil area, the irregular upper surface of the sand is capped at its highest points by a varying thickness of fine gas sand. The up-dip margin of accumulation has evidently been established by the lensing-out of the sand in this direction or by radical changes in the degree of pore space within the sand body.

The causes of accumulation at Pettus may be compared directly with those at Henne-Winch-Farris. The form of the sand body and the method of segregation of oil and gas in the sand are strikingly similar. The abrupt termination of the producing sand on the southwest end of the Pettus field, which is here attributed to erosional and depositional influences, has an interesting counterpart in the group of Mirando fields, extending northward from Aviators to Mirando City. The fields in this group are separated by narrow east-west zones in which only a very thin section of the sand is represented. Contours based on the top of the sand show sharp westward re-entrants which offer the false suggestion of structural closure.

In the Cosden and Grayburg fields, west of Pettus, the producing sand has been tentatively assigned to the *Dibollensis* zone, but no definite interval has been established between this sand and the "Pettus" hor-

izon. In the Cosden field, insufficient drilling has been accomplished to permit a satisfactory analysis of the conditions surrounding accumulation, but it is evident that the form of the sand body is somewhat different from that at Pettus. As outlined by the ten completed wells in the pool, the upper surface of the producing sand shows a distinct reversal in the direction of regional dip, from the gas wells on the south, to the northern margin of the oil area. This reversal, which amounts to about 50 feet in a distance of a half mile, may prove to be truly structural, but the history of regional production justifies the belief that it is depositional in character. The productive sand body is to be described as a sand lens in which deposition has raised the central part, relative to sea-level, above the level of the in-shore margin. The approximately flat reversal may be satisfactorily explained in this manner. Under such conditions, the apex of the sand body should contain gas as in a true dome. A second zone of gas production might be anticipated along the coastward margin of the sand body.

In the central Bee County territory, the several gas areas are productive from widely separated sands, between which it is impossible to establish definite intervals with our present knowledge. It is logical to believe that the large size of the initial gas wells in the Simms-Holzmark, the Nichols, and the Price-Weiss areas indicates fields of considerable size, but the limited data available at this time do not explain accumulation at these places. The manner of distribution of commercial gas in a wide area offers the suggestion of broad, gentle terracing of the Cole-Bruni type, but proof rests with the more thorough knowledge to be gained through continued prospecting.

SUMMARY

A summary of the factors controlling the accumulation of oil and gas in the Mirando district includes the following essential points. Commercial oil and gas deposits are confined to sands occurring within the 1,800-foot interval, which embraces strata of basal Frio, Fayette, and upper Yegua age. These sand bodies are the product of shore-line deposition, are lenticular in form, and follow definite trends, parallel with the regional formational contacts. Folding is absent, with the possible exception of the Carolina-Texas dome. The local function of faulting and fracturing is not clearly understood, but it is certain that their influence on oil and gas accumulation has been small. The source material from which the oil and gas have been derived was deposited at definite levels in the section and is indigenous to widespread sandy zones.

These zones constitute the productive group and all commercial oil and gas deposits are confined to one or more of its members.

In the Pettus district, the productive horizons are likewise confined to the 1,600-foot section of strata which lies between the basal Frio and the middle Yegua. From the standpoint of lithology, position of sands, and number of productive horizons, the two sections are strikingly alike. Paleontologically, these sections have only one common section of age equivalence, the basal 600 feet of the Fayette. Accumulation in the Pettus district has occurred under conditions almost identical with that in the type fields of the Mirando district. In the Pettus field proper, oil and gas have been trapped in a shore-line sand deposit where lenticularity was a primary factor. The comparison could undoubtedly be continued to include those other operative factors which have been described in detail.

CONCLUSIONS

A consideration of the data presented in this paper justifies the following conclusions.

1. The factors which have controlled the accumulation of oil and gas in the Mirando district have also constituted the primary factors in the Pettus district.

2. The productive section lies within the same stratigraphic limits in both districts and it is, therefore, to be considered that the sands within the Frio-Fayette-Yegua group of sediments constitute a potential source of oil and gas everywhere along the inner margin of the Gulf Coastal Plain of Texas.

3. The structureless character of the typical oil trap of this region reduces the effectiveness of the usual methods of geological study. Geological investigation will prove most profitable in the quest for new fields, when applied to a study of conditions in areas in which strike trends have already been established. It is not the attitude of the writer that a search for evidence of surface structure is entirely valueless. The function of faulting and fracturing is imperfectly understood and it is possible that surface fracturing and folding may point the way to commercial deposits of oil and gas in deep-seated sands. It must be understood, however, that most of such surface criteria will prove valueless in this connection.

DISCUSSION

Paul W. McFarland, Dallas, Texas: Mr. Brace has presented a comprehensive report on the Mirando area that is of special interest in connection with the recent development of the Jackson production in Bee and Goliad counties.

Since the peak of development was reached in the Mirando fields, an intensive paleontological study has been made of the Eocene formations in other areas, resulting in new divisions that can readily be recognized from samples. It is unfortunate that so few well samples from the Mirando area are available at the present time for comparison with the divisions of the Eocene elsewhere. As good samples are not available, we must depend upon a study of well logs in connection with certain key wells of which we have samples.

I do not agree with Mr. Brace's correlation of the producing "Mirando" sand in the Schott-Aviator field as being a higher horizon than the "B" zone in the Henne-Winch-Farris field. It is my opinion that his "Mirando" zone of the Schott-Aviator field, the "B" zone of the Carolina-Texas field, and the "B" zone of the Henne-Winch-Farris field should be correlated as the same zone, with the possibility that the "B" zone of the Henne-Winch-Farris field may be slightly higher in the section, although a part of the same general sand body. In the Carolina-Texas field the "B" zone consists of approximately 200 feet of sand and sandy shale. The 2,300-foot oil sand or "B" zone of the Bruni field is the top of a 300-foot zone of sand, sandy shale, and shale, which includes several separate layers of sand, the top one of which contains the accumulation of oil. In the Cole gas field the same zone has a thickness of 400 feet. It is my opinion that the 400-foot sandy zone is the equivalent of the 200-foot sandy "B" zone in the Carolina-Texas field. Such a condition would indicate a marked thickening of this part of the Fayette section similar to the thickening in the Pettus area, in other words a wedge of strata that is thickening down-dip. A study of samples and logs at the time of the development of the Aviator and Henne-Winch-Farris fields convinces me that the same interpretation should be placed on the producing sands of these two fields. Furthermore, the character of the oil in the 1,600-foot "pay" of the Schott-Aviator and the "B" zone of the Bruni and Henne-Winch-Farris fields is almost identical, having high lubricating qualities, and small gasoline content, but that of the 1,900-foot sand of the Schott field is of an entirely different type, having a high gasoline content and low lubricating qualities.

I agree with Mr. Brace's theory that the accumulation of oil in both the Mirando and Pettus areas is caused primarily by lenticular sand conditions. I would like to suggest, however, that there may be a definite relationship between folding and shore lines in the upper Eocene.

Mr. Brace states that, according to Deussen, the thickness of the Fayette at its outcrop north of the Pettus area does not exceed 500 feet. Detailed field work, checked by paleontological determinations of well samples, indicates conclusively that in Karnes and Gonzales counties, the Fayette has a thickness of approximately 1,000 feet. This thickness remains fairly constant down-dip as far as the northern part of Bee County. From northern Bee County southeastward the Fayette thickens rapidly. The zone of steep dip in northern Bee County, mentioned by Mr. Brace, begins just north of the Pettus producing area and seems to be the up-dip margin of the belt in which the Fayette and Jackson thicken rapidly toward the coast. In connection with this steeply dipping belt, a few fault exposures of small displacement are found at intervals from Live Oak County to DeWitt County, which almost without exception are normal faults downthrown toward the southeast. These faults considered

separately are of small importance, but, together with the steeply dipping strata already mentioned, seem to be a part of a zone of weakness or settling along the rim of the Gulf Coast basin. The rapid thickening of the Fayette down-dip from this feature indicates the possibility of some movement during its deposition. In other words, it is possible that such a line of weakness may have been the controlling feature of shore-line position during different phases of Fayette deposition.

L. P. TEAS, Houston, Texas: There are several points in Mr. Brace's paper relating to the Pettus area in Bee County that should be commented on because they are somewhat at variance with conclusions reached by studying the section of very many wells in this area, not only paleontologically but also lithologically. The statement is made that the lithology of the Jackson section at Mirando is identical with that at Pettus, although the paleontology shows marked differences. At Pettus the McElroy zone, 500 feet or more thick, is bentonitic, grayish brown to brownish, and consists almost entirely of shale. Such lithology as this, to my knowledge, has not been reported from the Mirando district. The clays of the Diboll zone are also dark blue to dark grayish brown and contain some glauconitic sand which is also unknown in the Mirando area. The sand of the Cockfield is sideritic, another feature not common with the Mirando. It is not necessary to disregard lithologic evidence and depend entirely upon fossils to show that a great change in the section has occurred between the Mirando and the Pettus districts, neither is it necessary to disregard lithologic evidence to show that the McElroy zone is delimited between the Pettus field and the outcrop, as the peculiar McElroy lithology has not been reported in any of the exposures in Karnes County. The inference from this paper is that the zone producing in the Mirando area is similar to the zone producing at Pettus. As a matter of fact, the producing sections are different in all respects; in fact, out of five producing horizons in the Pettus area only one occurs in a formation known in the Mirando area, namely, the basal Frio gas sand at 2,900 feet. As no reference is made to published paleontological data it is possible that misunderstanding may have arisen in verbally transmitting the ideas and notes referred to.

In the Pettus section shown in Figure 1, the Cosden sand is placed in the Diboll zone. This sand and the Grayburg-Kimball sand occur below definite Cockfield fossils. These sands can also be correlated on lithologic grounds with the productive sand at the Pettus townsite and in the wells at the east. The productive sand from the top of the McElroy, which has been designated the Holzmark sand, should be more properly called the Hicks sand, as it was on the Hicks land near Normanna that Nichols *et al.* brought in the first production from this horizon. As the Cartwright sand which is productive at Lucas occurs 60-133 feet below where Cockfield fossils were first noticed, it is probably the equivalent of the Pettus sand, rather than a sand much lower in the section. This, I believe, is the opinion of the operators at Lucas.

There are very grave objections to Mr. Brace's statement that the Pettus field is without structural influence and is located where the dip steepens on an unbroken, gulfward-dipping monocline. The theory that differences between wells on the top of the sand in the Cosden and other areas are not caused

by structure, but rather by the fact that this productive sand is a shore-line lens raised at the center by deposition, may be questioned. There is very definite structural evidence in the Pettus area that indicates both faulting and uplift. For example, there is a 160-foot drop in ½ mile southwest along the strike from the Glasscock well, Block 41, in the Pettus townsite, to the Trinity Drilling Company's Roberts No. 1. This seems to be too great a drop to be explained by any means other than faulting or structural dip. The Mauldin well, located just west of the Pettus townsite and midway between the Houston Oil Company's Portis No. 1 on the south and the Trinity Drilling Company's Roberts No. 1 on the north, is 63 feet higher than either of these wells.

From the Sun Company's Barnett No. 1, on the south side of the Cosden pool, there is a drop of 409 feet in 1 ⅓ miles down-dip to Morgan's Bay No. 1, and from the Cosden-McKinney No. 3 in the Cosden pool, 2 miles up-dip to the Southern Crude's Dahl No. 1, there is a drop in the contacts ranging from 24 feet on top of the Fayette to 162 feet on the Cockfield sand.

Perhaps the greatest indication of structure in the Pettus area is the fact that the Union Producing Company's Ray No. 30, although only a mile south of Morgan's McKinney No. 1, is 146 feet higher than that well, and 323 feet higher than the Union Producing Company's Ray No. 4, which is slightly more than ½ mile southeast. From this evidence we must conclude that there is a very pronounced dome here, or else place Ray No. 30 on an upthrust fault block. The latter interpretation seems better.

The evidence that a fault exists on the north side of the Pettus field is not so clear from differences on the top of the Pettus sand; however, it is definitely proved that such a fault must exist, because the Union Producing Company's Ray No. 6 encountered only 100 feet of Cockfield instead of the ordinary 250 feet or more. This well has seemingly crossed from the low side to the high side of the fault and the Pettus sand has been entirely cut out.

In view of the seeming structural condition at Pettus, it seems unnecessary to seek for some other explanation of oil accumulation, particularly since definite evidence for such explanations seems lacking.

In order to substantiate Mr. Brace's theory that the irregularity on the top of the producing sand at Pettus is caused by erosional or depositional features, it must be shown that this sand actually thins or vanishes in all directions from the field. This would be very difficult to show. Furthermore, the Pettus sand contains fossils which paleontologists say are not characteristic of a shore line and the sand can also be traced for some distance, not only in Bee County but in adjoining counties, as a continuous, definite sand member without the features characteristic of a lens. Many wells that have reached it found a good thickness of sand carrying salt water.

As it is known that at Raccoon Bend proximity to well established faults may reduce the ordinary amount of sand, it is possible to explain the thinning of the Pettus sand in this manner. The evidence of pronounced faulting is so sound from the scattered drilling, that many other faults, still so poorly known as to be unproved, may exist and further account for most of the sand thinning in Bee County.

The chalcedony masses at the surface and in wells at the Pettus townsite, Cosden area, and elsewhere strikingly correspond with known or suspected

faults; hence, we can not belittle the value of this and other surface evidence as a guide to the structural features of the area.

O. L. BRACE: To the reader who has just finished a perusal of the foregoing paper and of the appended discussion by Mr. Teas, it is evident that the digression of opinion between us is so wide that there is left little common ground of belief as to the controlling factors of accumulation of oil and gas in the Pettus District. In spite of Mr. Teas' statement that there is good lithologic as well as paleontologic evidence to support his interpretations, it is evident that paleontologic data form the groundwork of his ideas. In his discussion of the steep dip south of the Cosden pool, which he interprets as truly structural, a direct sand correlation is essential to support his contention. This is also true of the north flank of the Cosden pool, although I have recognized this feature within the immediate area of the field and have attempted to explain it on depositional grounds. In the picture which Mr. Teas presents of a complex system of faults, he draws his main support from the micro-faunal evidence furnished by well cuttings. In a controversy of this character, the proof necessarily rests with the degree of one's belief in the significance of detailed micro-faunal evidence. It is admittedly presumptuous to raise so fundamental a question against a well grounded science, but the amazing disagreement among paleontologists themselves upon the details of their conclusions causes one not versed in the science to wonder just how far their determinations may safely be accepted.

In discussing my conclusions with regard to Pettus, Mr. Teas endows me with a positiveness that I am far from feeling. I have approached the subject with hesitancy, recognizing that with our present knowledge, positive interpretations are impossible. I have attempted to present the thought that those sand members that act as oil and gas reservoirs in the Pettus and Mirando districts are mainly local, pure sand phases of widely distributed sandy zones. These porous phases, which I have referred to as lenses, have changed their position relative to the upper limit of the zone as frequently as local changes in depositional conditions occurred. Along an extensive front, under uniform conditions of deposition, these lenses would assume the form of long, narrow bodies, such as that at Henne-Winch-Farris, grading up-dip and laterally into sand of a less porous character, maintaining, however, their identity as a part of an extensive sandy zone. In the presence of cross-currents and sea-floor inequalities, the interference with this simple depositional process would break the single sand lens into several interfingering and overlapping lenses, with resulting steep dips and change of position of recognized sand members in their relation to the section. An example of such a condition exists in the Kohler field in Duval County, where the local occurrence of a new group of lenses creates a problem which might be solved by the introduction of a complex system of faults.

Mr. Teas' statement that the Pettus sand has been recognized in other parts of Bee County and in adjacent counties and that it is in places well developed and carries salt water, seems to be an argument for sheet sand development, in opposition to his interpretation of my theory of lenticularity as a primary factor in the control of accumulation. I am not at all certain that it

is possible for the paleontologist to carry sufficiently positive fossil correlations through considerable distances to be able to identify an individual sand member, and might therefore offer the argument of intermittent lensing of the Pettus sand to explain the presence of this horizon at distant points. I have, however, already advanced the idea of widespread distribution of the productive sandy zones and, therefore, do not insist on lenticularity except in so far as it affects the porosity of the sand reservoir.

In closing this reply, I should like to call attention to the fact that the importance of the structural theories which Mr. Teas has advanced to explain the control of oil accumulation at Pettus, depends on the time relationship between the occurrence of the faulting and uplift and the stabilization of migratory conditions within the reservoir beds which now contain the oil and gas. In my discussion of structural conditions at Mirando, I stressed the idea that faulting and fracturing might have cut the reservoir beds and still have exercised no primary influence over the oil and gas accumulated therein. Admitting, for the sake of argument, that the conception which Mr. Teas has advanced is correct, does it necessarily follow that faulting and uplift were primary factors controlling accumulation and that surface indication of like faulting and uplift in adjacent areas could logically be accepted as presaging a repetition of an accumulation of oil and gas such as is known to occur at Pettus?

TAYLOR AGE OF SAN MIGUEL FORMATION OF MAVERICK COUNTY, TEXAS[1]

LLOYD WILLIAM STEPHENSON[2]
Washington, D. C.

ABSTRACT

The San Miguel formation of Maverick County, Texas, has generally been correlated with the Navarro formation of central Texas, except by F. M. Getzendaner and the writer. The formation contains many long-ranging species which occur elsewhere in beds of both Taylor and Navarro age, but it also contains species of restricted range, which indicate its upper Taylor age. The formation contains a varietal form of *Exogyra costata* Say, but lacks the true *costata* and also lacks other diagnostic Navarro species.

There is an important faunal hiatus between the San Miguel formation and the Escondido, the next higher formation which carries a marine fauna; this break is only partly filled by the Olmos ("Coal series"), an essentially non-marine formation.

The hiatus which exists in the outcropping section may be partly or wholly filled down the dip, under cover, by marine beds representing the lower part of the typical Navarro formation of central Texas.

The San Miguel formation was first differentiated and named by Dumble[3] in 1892. He divided the Upper Cretaceous series of Maverick and adjacent counties, in ascending order, into the Val Verde flags, the Pinto limestone, and the Eagle Pass division. His Val Verde flags corresponded to the Eagle Ford shale, his Pinto limestone to the Austin chalk, and his Eagle Pass division to the remainder of the Upper Cretaceous series. He subdivided his Eagle Pass division into the Upson clay, the San Miguel beds, the "Coal series," and the Escondido beds. He correlated the Upson clay with the *Ponderosa* marls (Taylor marl), the San Miguel beds with the "Glauconitic beds" (Navarro formation), and he considered the Escondido beds as unrepresented in the Colorado River section.

Vaughan and Stanton,[4] as a result of a reconnaissance along the Rio Grande in 1895, correlated the Upson clay with the Taylor marl, and the

[1]Read before the Division of Paleontology and Mineralogy of the Association at the San Antonio meeting, March 20, 1931. Manuscript received, March 3, 1931. Published by permission of the acting director, U. S. Geological Survey.

[2]Chief, Section of Coastal Plain Investigations, U. S. Geological Survey.

[3]E. T. Dumble, "Notes on the Geology of the Valley of the Middle Rio Grande," *Bull. Geol. Soc. Amer.*, Vol. 3 (1892), pp. 219-30.

[4]T. W. Vaughan, "Reconnaissance in the Rio Grande Coal Fields of Texas," *U. S. Geol. Survey Bull. 164* (1900). 72 pp.

San Miguel beds with the Ripley formation of Mississippi, the Navesink formation of New Jersey, and inferentially with the Navarro formation of Kaufman and Navarro counties, Texas. Stanton thought that the fauna of the Escondido formation is of Ripley age, but supposed that the Escondido probably includes, in its upper part, beds more recent than the latest Ripley beds of Mississippi and Alabama.

Stephenson,[1] in 1927, and again in 1928,[2] correlated the combined Upson clay and San Miguel formation with the Taylor marl and equivalent beds.

Böse,[3] in 1927, correlated the San Miguel beds with the Navarro formation, probably on the evidence mainly of shells which he regarded as typical of *Exogyra costata* Say.

Vanderpool,[4] in 1930, correlated the San Miguel with the lower part of the Navarro formation, although he made no paleontologic comparison between the two formations with respect to either the larger or the smaller fossils.

Getzendaner,[5] in 1930, regarded the San Miguel beds as of late Taylor age, although he could see no evidence of a pronounced faunal break at the top of the formation.

Because of the confusion arising from the conflicting age assignments, it has seemed desirable to review the evidence and to ascertain, if possible, the true position of the San Miguel formation in the geologic column of Texas. With this in view, the writer has re-examined the available collections, approximately twenty, and has made collections at two additional localities in the field, and concludes that the formation is of upper Taylor age.

The formation consists of soft to hard, massive to cross-bedded, more or less calcareous sandstone, sandy and argillaceous limestone, and interbedded layers of fine, more or less argillaceous, calcareous sand and

[1] L. W. Stephenson, "Notes on the Stratigraphy of the Upper Cretaceous Formations of Texas and Arkansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 1 (January, 1927), pp. 1-17, correlation chart, Pl. 1.

[2] L. W. Stephenson, "Correlation of the Upper Cretaceous or Gulf Series of the Gulf Coastal Plain," *Amer. Jour. Sci.*, 5th Ser., Vol. 16 (1928), pp. 485-96, correlation chart, Fig. 1.

[3] Emil Böse, "The Cretaceous and Tertiary of Southern Texas and Northern New Mexico," *Texas Univ. Bull. 2748* (1927), pp. 13, 44-47.

[4] H. C. Vanderpool, "Cretaceous Section of Maverick County, Texas," *Jour. Paleont.*, Vol. 4 (1930), No. 3, pp. 252-58.

[5] F. M. Getzendaner, "Geologic Section of Rio Grande Embayment, Texas, and Implied History," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 11 (November, 1930), pp. 1425-37.

calcareous sandy and non-sandy clay. These materials are gray in fresh exposures but weather to yellowish, greenish, and brownish tints. The indurated layers are generally fossiliferous, as are also some of the unindurated layers. The unindurated layers probably predominate in thickness over the indurated layers, but more of the indurated layers are seen in outcrop because of their more effective resistance to erosion. The limestones resemble those of the Anacacho except that they are generally more sandy and argillaceous. The thickness of the formation is estimated to be somewhat more than 400 feet.

The writer has not seen the shells which Böse identified as *Exogyra costata* Say, but among the collections studied are many specimens which represent the varietal form of *E. costata* to which the writer formerly applied the name *spinosa*. As this name is now known to be preoccupied, the variety will have to be re-named. The known stratigraphic range of this variety is from the upper part of the *Exogyra ponderosa* zone into the lower part of the *Exogyra costata* zone, that is, from the upper part of the Taylor marl into the lower part of the Navarro formation. The critical consideration in the present problem is that in the San Miguel formation of Maverick County this varietal form occurs in association with large, smooth shells of *E. ponderosa* Roemer, such as are unknown in the Navarro formation, and are nowhere known to range above the *Exogyra ponderosa* zone.

If it were to be admitted that, in this area, *E. ponderosa* does range higher than elsewhere, and that the San Miguel formation is of lower Navarro age, the formation should also contain *E. cancellata* Stephenson, a characteristic lower Navarro species. The environmental conditions in the San Miguel sea were obviously favorable for the existence and growth of the large forms of *Exogyra*, and *E. cancellata* has a known geographic range from New Jersey past the Rio Grande region to the State of San Luis Potosi, Mexico; it should, therefore, have lived in the intermediate San Miguel sea. The same argument would apply also to *E. ponderosa;* there seems to be no reason why this species, if it lived on into Navarro time in the Rio Grande region, should not have done so elsewhere in the Atlantic and Gulf Coastal plain. The absence of *E. cancellata* from the San Miguel formation may therefore be reasonably accepted as negative evidence, and the presence of large smooth shells of *E. ponderosa* as positive evidence, of the Taylor age of the formation.

The San Miguel formation has yielded a fairly large fauna, many species of which are long-ranging, and occur in both the Taylor marl and

the Navarro formation, and in beds of equivalent age; but some of the species are of more restricted range and tend to confirm the Taylor age of the formation. The species shown in the following list have been identified from the formation. Many forms not listed have been determined only generically; of these, some are undescribed species. The species in the list marked with an asterisk (*) are regarded as indicating the Taylor age of the formation.

PARTIAL LIST OF SPECIES FROM SAN MIGUEL FORMATION

***Nemodon* aff. *N. punctus* Stephenson
Ostrea plumosa Morton
Ostrea saltillensis Böse (numerous)
***Ostrea* n. sp.
***Exogyra ponderosa* Roemer (large and numerous in places)
***Exogyra costata* Say (a variety, numerous in places)
Pecten simplicius Conrad
Pecten aff. *P. mississippiensis* Conrad
Anomia sp. (numerous)
Liopistha (*Cymella*) *bella* (Conrad)
Cardium (*Pachycardium*) *spillmani* Conrad
***Cardium* aff. *C. carolinensis* Conrad
Cardium (*Ethmocardium*) n. sp.
Veniella conradi (Morton)
Cyprimeria depressa Conrad
***Turritella* aff. *T. quadrilira* Johnson (numerous)
Pugnellus n. sp. (numerous)
Placenticeras sp.

Of the species listed, *Ostrea saltillensis* Böse is one of the most common in the formation, having been found at no less than fourteen of the twenty-two fossil localities represented by the collections. The species ranges downward into the underlying Upson clay, but does not occur above the San Miguel. Geographically the species ranges southward into equivalent beds in Mexico, at least as far as the vicinity of Saltillo in Coahuila, but is not known east of Maverick County, in Texas.

The *Turritella*, which is compared with *T. quadrilira* Johnson, is characterized by four sharp revolving lirae, the upper one of which is weaker than the other three. This type of *Turritella* has its best development in beds of Taylor age, and is plentifully represented in the San Miguel formation.

The ammonite genus *Placenticeras* is of common occurrence in beds of Taylor age, but is found only rarely in beds of lowest Navarro age. One large species is known in the *Exogyra cancellata* zone of the Navarro formation but the genus is wanting in the three upper members of the Navarro formation. *Placenticeras* and *Sphenodiscus* are never found to-

gether, and *Sphenodiscus* makes its earliest appearance in the Nacatoch sand member of the Navarro.

The new species of *Ostrea* indicated in the list was found in a small branch near the east side of section 81, 1¾ miles east by north of Rycade Sullivan well No. 5 on the Chittim ranch, in a yellowish, soft to moderately hard, calcareous sandstone which, according to L. W. MacNaughton, lies within 100 feet of the top of the San Miguel formation. The same species occurs in a 20-foot exposure of impure limestone and interbedded calcareous sand, in a bluff on Muela Creek just south of the Flowers ranch house (old Beasley ranch), 2 miles northwest of the southeast corner of Kinney County. Both T. Wayland Vaughan[1] and the writer have correlated this section with the Anacacho limestone, and the writer regards the occurrence here of this new species of *Ostrea* as strong confirmatory evidence of the upper Anacacho age of the San Miguel formation.

The Olmos formation ("Coal series"), which overlies the San Miguel, is essentially a non-marine unit, but a marine fauna appears in the lower part of the Escondido, the next overlying formation. Although the fauna found in the lower Escondido is a shallow-water facies different in most respects from that carried by equivalent beds in central Texas, there is one species which is very significant in correlation. It is a varietal form of *Exogyra costata* characterized by well developed but narrow costae. This variety occurs in central Texas in the chalky marl member and in the upper clay member of the Navarro formation, which lie above the Nacatoch sand member. The forms of *Exogyra costata* with medium and broad costae, which characterize the lower part of the *Exogyra costata* zone throughout most of the Atlantic and Gulf Coastal Plain, are wanting in the Maverick County section. *Exogyra cancellata*, which characterizes the lower member of the Navarro formation in central Texas, is also completely wanting in this section.

Another very significant feature of the faunal make-up of the lower Escondido is the occurrence in considerable numbers of several species of the ammonite genus *Sphenodiscus*. This genus is wanting in central Texas in the *Exogyra cancellata* zone of the Navarro formation, it occurs only rarely in the Nacatoch sand and in the chalky marl member of that formation, and it becomes an important faunal element only in the upper clay member.

The evidence, therefore, indicates that an important faunal hiatus exists between the top of the San Miguel formation and the base of the

[1]Unpublished manuscript map of the Brackett Quadrangle.

Escondido formation. This break is partly filled by the non-marine Olmos formation.

What has been said in preceding paragraphs pertains to the Maverick County section as it is revealed in outcrops. Well data given by Getzendaner[1] suggest that the wide hiatus which exists in the outcropping section may be largely, or perhaps completely, filled by successively older beds which come in down the dip under cover, and which represent the lower part of the Navarro formation of central Texas.

The age relationships of the San Miguel formation of Maverick County to the Taylor and Navarro formations of central Texas, as here interpreted, are shown in Figure 1.

DISCUSSION

H. C. VANDERPOOL, Houston, Texas: I am sure that Dr. Stephenson is much better acquainted with the various species of *Exogyra* and other large fossils than I am. However, there are a few points that I should like to discuss briefly.

In the first place, I think this discussion involves a most important question which will have to be decided sooner or later. This question is, which class of fossils, megascopic or microscopic, have the greatest value for correlating purposes? In my paper on the "Cretaceous Section of Maverick County, Texas," as mentioned by Dr. Stephenson, I placed the San Miguel formation in the Navarro after studying the micro-fauna in subsurface samples. Practically every micro-paleontologist who has worked in this part of the section in Maverick and Dimmit counties agrees with my correlation. It is my suggestion that samples from the type locality as well as subsurface samples from the San Miguel be submitted to Dr. Cushman for his check of the micro-fauna.

In the second place, I should like to remind you that a good break does exist between the San Miguel and the Upson formation below. Any geologist who has worked in the Maverick county area will recall the Upson clays with plentiful *Exogyra ponderosa* and the gray, calcareous sandstones and sandy clays containing varieties of *E. costata* and a few small *E. ponderosa* that make up the lower part of the San Miguel formation. The difference in lithology is definite; the change in macro-fauna is also quite apparent. In my opinion, the appearance of a new species or variety, whether megascopic or microscopic, is much more significant than the carrying through of an old form. In other words, I see no good reason why the carrying over of a few *E. ponderosa* into the base of the San Miguel establishes the Taylor age of that unit, especially if the micro-fauna is Navarro (Velasco) in aspect.

L. W. STEPHENSON: The question of the relative values in correlation of the marine organisms of megascopic and microscopic size, is one which can not be arbitrarily settled by any one man, or any group of men. The question can be settled only by a long continued critical study of these organisms by special-

[1] *Op. cit.*, pp. 1432-33.

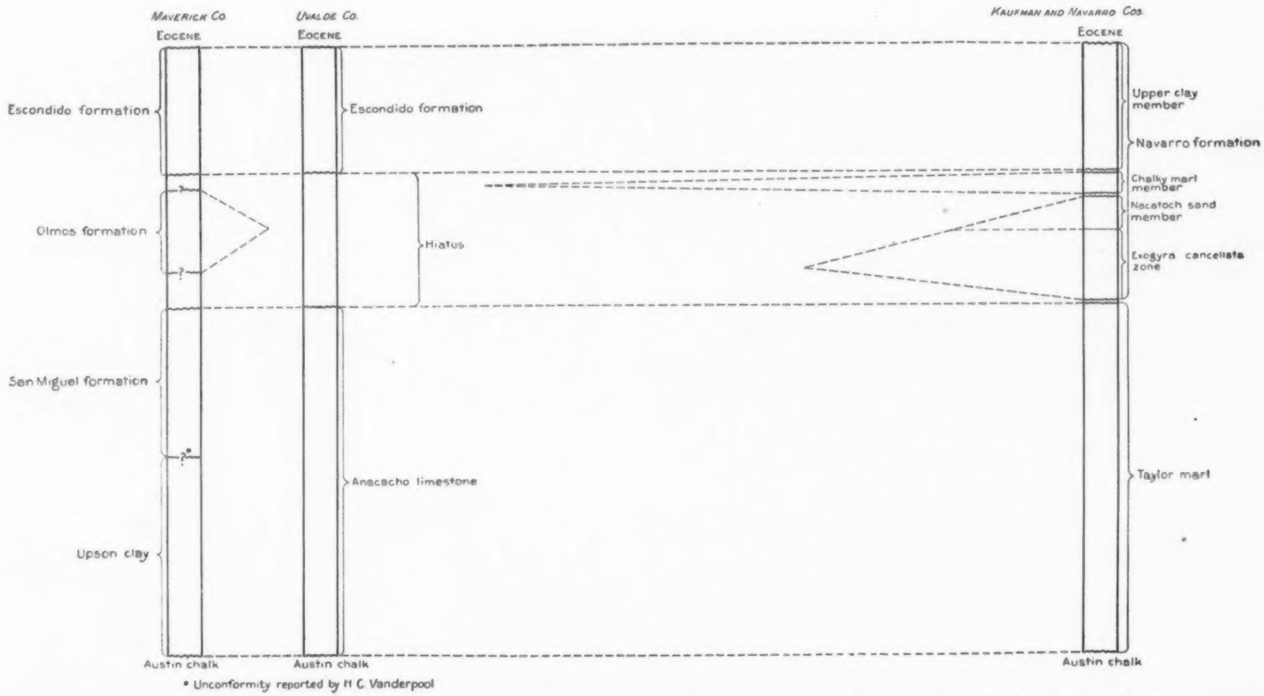


FIG. 1.—Correlation of Upper Cretaceous formations above Austin chalk in Maverick and Uvalde counties, with Taylor and Navarro formations of Kaufman and Navarro counties.

ists who are qualified both to classify them and to determine the ranges of the recognized species. When the verdict is finally written, if it ever is, many species of each class will be found to have definite value in correlation, and the story which the species in one class tells will be in harmony with that told by the species in the other class. It is inconceivable that, with all the essential facts known, the megascopic and microscopic faunas from the same formation should afford conflicting evidence of the age of that formation. The trouble lies not in the fossils themselves, but in the inaccuracy of our determination of species, and in our ignorance of their ranges.

The presence of a stratigraphic break between the Upson clay and the San Miguel formation is not in itself evidence of the Navarro age of the San Miguel. It merely means that there was uplift and erosion, or an interruption to sedimentation, between the deposition periods of the two formations.

The appearance of new species or varieties in a formation may or may not be significant of the younger age of the formation. Some of the new species found in the Navarro formation in its type area doubtless migrated into the Navarro sea from outside regions and such species, if found in the San Miguel formation, would indicate its Navarro age. There is considerable evidence, however, if it were all assembled, that many of the seemingly new Navarro forms had their evolutionary development in the Gulf region during Taylor time, in shallow shoreward facies of the Taylor sediments, most of which have been subsequently destroyed by erosion. I am inclined to regard the San Miguel formation as one of those shallow-water facies which escaped destruction by reason of its having been downwarped in the Rio Grande synclinorium; if so, it should be a favorable place to look for the ancestors of the new Navarro species. These ancestors, if found, may be expected to be very much like their successors, and this might explain the Navarro-like aspect of San Miguel faunas.

PRE-CRETACEOUS ROCKS FOUND IN WELLS IN GULF COASTAL PLAIN SOUTH OF OUACHITA MOUNTAINS[1]

HUGH D. MISER[2] and E. H. SELLARDS[3]
Washington, D. C., and Austin, Texas

ABSTRACT

Deep wells that have been drilled in the part of the Gulf Coastal Plain south of the Ouachita Mountains have passed through gently inclined Cretaceous strata and entered Paleozoic rocks. The Paleozoic floor, which is relatively smooth, has a steep southerly dip; therefore, it has not been reached by wells at great distances from the mountains. It has, however, been reached at many places in a wide southwestward trending belt that extends from Oklahoma into Texas. The wells that are described in this paper include a few in southwestern Arkansas, a few in southeastern Oklahoma, and several in Grayson, Fannin, Lamar, and Red River counties, Texas. The Paleozoic rocks that have been penetrated by these wells are similar in character and age to the Paleozoic rocks exposed in the Ouachita Mountains.

Some of the wells in the counties adjacent to Red River in Texas have entered pre-Carboniferous rocks. Areas of such rocks are perhaps southwestward extensions of the exposure of rocks of this age in the Ouachita Mountains in Oklahoma. The other wells within the area described entered rocks that are assigned to the Carboniferous or simply to the Paleozoic. There seems to be no evidence that any of the wells entered pre-Cambrian rocks.

The western boundary of the Ouachita Mountain facies of rocks seems to pass in a southerly direction through the western part of Grayson County, Texas. West of this boundary are Paleozoic rocks that are similar to those exposed in the Arbuckle and the Wichita Mountains and Criner Hills. This boundary, the writers believe, is marked by a southwestward continuation of the Choctaw fault from Oklahoma.

The axis of the Ouachita geosyncline—the geosyncline in which the rocks of the Ouachita Mountain facies were deposited—has an east-west trend in Arkansas, but it swings toward the southwest in Oklahoma and crosses Red River into Texas. The part of the geosyncline extending from Arkansas across Oklahoma into Texas thus displays an arcuate form.

DISTRIBUTION OF WELLS

A considerable number of wells that have been drilled in the part of the Gulf Coastal Plain south of the Ouachita Mountains have penetrated Paleozoic rocks, which form a relatively smooth floor underneath the gently inclined Cretaceous rocks. As this floor has a southerly dip

[1]Published by permission of the director of the U. S. Geological Survey. Read before the Association at the New Orleans meeting, March 20, 1930. Manuscript received, March 10, 1931.

[2]Geologist, U. S. Geological Survey.

[3]Associate director, Bureau of Economic Geology.

ranging from 70 to 250 feet to the mile,[1] it has not been reached by wells more than 25 miles south or 40 miles southeast of the Ouachita Mountains. It has, however, been reached by wells at many places farther southwest, in a wide southwestward trending belt[2] that extends from Oklahoma into Texas. Some of these wells are described in the present paper, including a few in southwestern Arkansas, several in southeastern Oklahoma, and several in Red River, Lamar, Fannin, and Grayson counties, Texas.

GENERAL GEOLOGIC RELATIONS

Wells that have reached the basement rocks south of the Ouachita Mountains are of special interest, not only because they reveal rocks similar in character and age to those that are exposed in these mountains, but also because they afford evidence on the direction and extent of the Ouachita geosyncline underneath the Cretaceous and Tertiary sediments of the Gulf Coastal Plain. Much information is now available on the southwesterly extension of the Ouachita geosyncline from Oklahoma into Texas. Such information as is available from deep wells is given in the present paper and in one in this number of the *Bulletin* by Sellards on the pre-Cretaceous rocks of northeast-central Texas, and has also been briefly mentioned in two papers, one by Sellards[3] and another by Cheney,[4] already cited.

[1]L. W. Stephenson, "A Contribution to the Geology of Northeastern Texas and Southern Oklahoma," *U. S. Geol. Survey Prof. Paper 120* (1919), pp. 158-59.

H. D. Miser and A. H. Purdue, "Asphalt Deposits and Oil Conditions in Southwestern Arkansas," *U. S. Geol. Survey Bull. 691* (1919), p. 275.

C. W. Honess, "Geology of Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties, Oklahoma," *Oklahoma Geol. Survey Bull. 40-R* (1927), pp. 18-20.

F. A. Melton and F. H. McGuigan, "The Depth of the Base of the Trinity Sandstone and the Present Attitude of the Jurassic Peneplain in Southern Oklahoma and Southwestern Arkansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 10 (October, 1928), p. 1011.

H. C. Vanderpool, "A Preliminary Study of the Trinity Group in Southwestern Arkansas, Southeastern Oklahoma, and Northern Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 11 (November, 1928), pp. 1090-92.

C. H. Dane, "Upper Cretaceous Formations of Southwestern Arkansas," *Arkansas Geol. Survey Bull. 1* (1929), pp. 11-12.

H. D. Miser and A. H. Purdue, "Geology of the DeQueen and Caddo Gap Quadrangles, Arkansas," *U. S. Geol. Survey Bull. 808* (1929), pp. 137-38, 184-85.

[2]M. G. Cheney, "History of the Carboniferous Sediments of the Mid-Continent Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 6 (June, 1929), p. 583, Fig. 7; "Stratigraphic and Structural Studies in North-Central Texas," *Texas Univ. Bull. 2913* (1929), Pl. 7.

E. H. Sellards, "Preliminary Map of Underground Position of Pre-Cambrian in Texas," *Texas Univ. Bur. Econ. Geol. Cir. 8* (1929).

[3]E. H. Sellards, "Preliminary Map of Underground Position of Pre-Cambrian in Texas," *Texas Univ. Bur. Econ. Geol. Cir. 8* (1929).

[4]M. G. Cheney, "Stratigraphic and Structural Studies in North-Central Texas," *Texas Univ. Bull. 2913* (1929), Pl. 7.

From well data, we anticipate that much information will be obtained that will bear on the moot question of the relation of the Ouachita geosyncline to the Appalachian geosyncline.

The axis of the Ouachita geosyncline has an east-west trend in Arkansas, but swings southwest in Oklahoma and crosses Red River into Texas. The form thus displayed by it in these states is markedly arcuate.

The Ouachita Mountains of Oklahoma and Arkansas constitute a relatively small geologic unit, 220 miles long, whose rocks and geologic structure are different from those of the adjacent regions. Their geology is described in many reports, some of which are here cited.[1] The rocks have been deformed by folding and faulting. They consist mostly of shale and sandstone, with some chert, novaculite, limestone, and tuff, and are of many ages—Cambrian, Ordovician, Silurian, Devonian, Mississippian, and early Pennsylvanian (Pottsville). Their aggregate thickness is 25,000 feet. Exposures of igneous rocks are confined to a few areas of small size. Pre-Cambrian rocks are not exposed anywhere, nor have they been reached by deep wells.

CHARACTER OF WELL DATA AND GEOLOGIC CONCLUSIONS

The wells herein described include a considerable number from which cuttings have been available for examination by members of the United States Geological Survey and the Texas Bureau of Economic Geology. The list given in Table I includes also a few of the many wells from which cuttings are not available. Although drillers' logs for many wells have been consulted, they are not very useful, because the true character of the pre-Cretaceous rocks can not be determined or even inferred satisfactorily from them, nor can they be relied on for locating accurately the base of the Cretaceous rocks in all the wells.

[1]A. H. Purdue and H. D. Miser, *U. S. Geol. Survey Geol. Atlas, Hot Springs Folio 215* (1923).

C. W. Honess, "Geology of the Southern Ouachita Mountains of Oklahoma," *Oklahoma Geol. Survey Bull. 32* (1923); "Geology of Southern LeFlore and Northwestern McCurtain Counties, Oklahoma," *Oklahoma Bur. Geol. Cir. 3* (Norman, Oklahoma, 1924).

H. D. Miser, "Geologic Map of Oklahoma," *U. S. Geol. Survey* (1926).

E. O. Ulrich, "Fossiliferous Boulders in the Ouachita 'Caney' Shale and the Age of the Shale Containing Them," *Oklahoma Geol. Survey Bull. 45* (1927).

Sidney Powers, "Age of Folding of the Oklahoma Mountains," *Bull. Geol. Soc. Amer.*, Vol. 39 (1928), pp. 1031-79.

H. D. Miser and A. H. Purdue, "Geology and Mineral Resources of the DeQueen and Caddo Gap Quadrangles, Arkansas," *U. S. Geol. Survey Bull. 808* (1929).

G. C. Branner, "Geologic Map of Arkansas," *Arkansas Geol. Survey* (1929).

H. D. Miser, "Structure of the Ouachita Mountains of Oklahoma and Arkansas," *Oklahoma Geol. Survey Bull. 50* (1929).

Identifiable fossils have not been found in the cuttings of pre-Cretaceous rocks from most of the wells here described, and most age assignments are thus based on lithologic character alone.

One well, the Lady Alice No. 1, at Silver City, Red River County, Texas, penetrated rocks that are either Cambrian or Ordovician, as is

TABLE I

PRE-CRETACEOUS ROCKS FOUND IN WELLS IN SOUTHWESTERN ARKANSAS, SOUTHEASTERN OKLAHOMA, AND NORTHEASTERN TEXAS

(Numbers correspond with those on Figure 1)

	Name of Well	*State and County*	*Rocks Penetrated*
		Arkansas	
1.	Eagle Lumber Company's No. 1	Dallas County	Paleozoic quartzite
2.	Dudley *et al.* Owen No. 1	Dallas County	Paleozoic quartzite
3.	Perpetual Oil and Gas Company	Howard County	Carboniferous shale and sandstone
		Oklahoma	
4.	Bokhoma	McCurtain County	Paleozoic rocks
5.	Louisiana Petroleum Company	McCurtain County	Paleozoic shale and sandstone
6.	Oklahoma - Colorado Oil and Gas Company's No. 1	Choctaw County	Stanley shale (Mississippian)
7.	Trojan Home Builders Nash	Pushmataha County	Jackfork sandstone (Mississippian)
8.	Gillam and Foster Company's Wade No. 1	Choctaw County	Jackfork sandstone
9.	Hansen *et al.*	Atoka County	Caney shale (Pennsylvanian and Mississippian) to Simpson formation (Ordovician); Arbuckle Mountain facies of rocks
		Texas	
10.	Lady Alice No. 1	Red River County	Ordovician or Cambrian
11.	Bailey Development Company's Ford No. 1	Lamar County	Stanley shale or Ordovician
12.	Elkay Oil Company's No. 1	Fannin County	Stanley shale
13.	Parsons	Fannin County	Stanley shale
14.	Peter Oils, Inc., Butcher No. 1	Grayson County	Stanley shale
15.	O'Dell	Grayson County	Missouri Mountain shale (?) (Silurian) and Polk Creek shale (?) (Ordovician)
16.	Preston No. 1	Grayson County	Stanley shale
17.	Preston No. 2	Grayson County	Stanley shale
18.	Wall No. 1	Grayson County	Bigfork chert and Stringtown shale (Ordovician)
19.	Westover *et al.* Easton No. 1	Grayson County	Stanley shale

revealed by a complete set of cuttings from the basement rocks. Another well, the Bailey Development Company's Ford No. 1, 14 miles north-northwest of Paris, Lamar County, Texas, entered the Stanley shale (Mississippian) or a formation of Ordovician age.

The discovery of Cambrian or Ordovician rocks in the Lady Alice No. 1 and possibly in the Ford No. 1 is of special scientific interest, because it suggests that a wide belt of pre-Carboniferous rocks extends from the Ouachita Mountains of northern McCurtain County, Oklahoma, in a southwesterly direction to and beyond Red River. The pre-Carboniferous rocks in McCurtain County are closely folded and much faulted, are considerably metamorphosed, and are cut by many veins and pegmatite dikes composed largely of quartz, with some feldspar and calcite. They crop out on the southern margin of the Ouachita Mountains, and the nearest exposures are about 16 miles northeast of the Lady Alice No. 1.

A similar, though narrower, belt of pre-Carboniferous rocks underneath the Cretaceous occurs near Denison, Texas, as is indicated by the discovery of the Bigfork chert and the Stringtown shale, both Ordovician, in the Wall well No. 1 in the Pottsboro gas field 6 miles west of Denison, and by the discovery of what may be the Missouri Mountain shale (Silurian) and the Polk Creek shale (Ordovician) in the O'Dell well, 2 miles southeast of Denison. This belt may be a southwestward continuation of the belt of pre-Carboniferous rocks that are exposed at Atoka, Oklahoma. The pre-Carboniferous rocks there consist of the Arkansas novaculite (Devonian), the Missouri Mountain shale (Silurian), and the Polk Creek shale, Bigfork chert, and Stringtown shale, all three of which are Ordovician.

The Stanley shale (Mississippian) has been penetrated in several wells in Oklahoma and Texas, and the Jackfork sandstone (Mississippian) in two wells in Oklahoma. The rocks in the other wells are assigned simply to the Carboniferous or Paleozoic.

No wells in the area here described seem to have entered pre-Cambrian rocks, though some authors[1] have referred to the altered rocks that have been found in deep wells in Red River, Lamar, and Grayson counties, Texas. These wells include the Lady Alice No. 1 and Ford No. 1 and seem also to include the Peter Oils, Inc., No. 1, Butcher lease.

[1]Sidney Powers, "Age of the Folding of the Oklahoma Mountains," *Bull. Geol. Soc. Amer.*, Vol. 39 (1928), p. 1045, footnote.

E. H. Sellards, "Preliminary Map of Underground Position of Pre-Cambrian in Texas," *Texas Univ. Bur. Econ. Geol. Cir. 8* (1929).

M. G. Cheney, "History of the Carboniferous Sediments of the Mid-Continent Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 6 (June, 1929), p. 583, Fig. 7.

FIG. 1.—Map of parts of Arkansas, Oklahoma, and Texas, showing wells that have entered pre-Cretaceous rocks. Details of wells 12-19 are shown in insert. The numbers of the wells correspond with those given in Table I.

The wells here described that entered pre-Cretaceous rocks in Grayson County, Texas, are all near Denison—the Peter Oils, Inc., No. 1, Butcher lease, 2½ miles east of the city; the O'Dell, 2 miles southeast; the Preston No. 1, 2 miles north; the Preston No. 2, 2½ miles north; the Wall No. 1, 6 miles west; and the Westover *et al.* Easton No. 1, 9 miles northwest. The Paleozoic rocks revealed in these wells and in all the described wells farther east in Texas, Oklahoma, and Arkansas belong to the sequence that is exposed in, and is confined mainly to, the Ouachita geosyncline. None of the wells penetrating pre-Cretaceous rocks in extreme western Grayson County and adjacent counties has, so far as known, entered rocks that are characteristic of the sequence in the Ouachita geosyncline. However, all wells[1] that have been drilled into the pre-Cretaceous rocks in extreme western Grayson County and adjoining parts of counties on the north, west, and south have entered Carboniferous and older formations that seem to be similar to the rocks exposed in or near the Arbuckle and Wichita Mountains and the Criner Hills of Oklahoma.

The western boundary of the Ouachita Mountain facies may thus pass in a southerly direction across Grayson County, west of Denison. This is a suggestion which accords with the opinion that has been offered by Sellards.[2] The westernmost wells that are known to reveal the Ouachita Mountain facies of rocks are the Wall No. 1, in the Pottsboro gas field, 6 miles west of Denison, and the Westover *et al.* Easton No. 1, 9 miles northwest of Denison. The inference that the western boundary of this facies of rocks passes near the wells seems to be strengthened by their location on a slightly arcuate line that connects the part of the Choctaw fault, near Atoka, Oklahoma, with the "steep dip zone of Ouachita overthrusting," as shown in northeast-central Texas by Cheney.[3] This "steep dip zone" is represented by Cheney as marking the

[1]O. B. Hopkins, Sidney Powers, and H. M. Robinson, "The Structure of the Madill-Denison Area, Oklahoma and Texas, with Notes on Oil and Gas Development," *U. S. Geol. Survey Bull. 736* (1923), pp. 30-31.

F. M. Bullard, "Geology of Marshall County, Oklahoma," *Oklahoma Geol. Survey Bull. 39* (1926), pp. 58-71.

H. P. Bybee, F. M. Bullard, and E. M. Hawtof, "The Geology of Cooke County, Texas," *Texas Univ. Bull. 2710* (1927), pp. 44-45, 63 *et seq.*

Sidney Powers, "Age of the Folding of the Oklahoma Mountains," *Bull. Geol. Soc. Amer.*, Vol. 39 (1928), pp. 1060-62.

M. G. Cheney, Stratigraphic and Structural Studies in North-Central Texas," *Texas Univ. Bull. 2913* (1929), Pl. 7.

[2]E. H. Sellards, "Preliminary Map of Underground Position of Pre-Cambrian in Texas," *Texas Univ. Bur. Econ. Geol. Cir. 8* (1929), p. 2 and Pl. 1.

[3]M. G. Cheney, "Stratigraphic and Structural Studies in North-Central Texas," *Texas Univ. Bull. 2913* (1929), Pls. 2, 3, and 7.

western boundary of the southwest extension of the Ouachita geosyncline. In Oklahoma the part of the Choctaw fault that is exposed near Stringtown and Atoka marks the boundary between the Ouachita Mountain and Arbuckle Mountain facies of rocks.

The Choctaw fault passes out of sight where it reaches the edge of the Coastal Plain near Atoka, Oklahoma. Its full length is therefore not known, but it surely extends southwestward many miles underneath the Cretaceous strata. The possible position of the Choctaw fault underneath the Coastal Plain for a distance of 10 miles southwest of Atoka is shown in Figure 1. This position is seemingly determined from the Hansen *et al.* well,[1] (No. 9, Fig. 1), in the SE. ¼, NW. ¼, Sec. 17, T. 4 S., R. 11 E., Atoka County, Oklahoma, which did not penetrate rocks of the Ouachita Mountain facies, but instead encountered rocks of the Arbuckle Mountain facies (a normal section from the Carboniferous Caney shale down to the Ordovician Simpson formation) from comparatively shallow depths to the bottom of the hole.

The regional relations just outlined seem to support the suggestion that the Choctaw fault extends in a southwestward direction to and beyond the vicinity of Denison, Texas. This city is about 50 miles southwest of Atoka, Oklahoma, where the fault passes out of sight underneath the Coastal Plain, and is about 40 miles southwest of the Hansen *et al.* well previously mentioned.

WELLS IN SOUTHWESTERN ARKANSAS

Many wells in the Coastal Plain of southern and southeastern Arkansas have reached the basement rocks at distances as far away as 40 miles southeast of the Ouachita Mountains, but there seem to be relatively few wells that have reached the basement rocks in the southwest part of the state, the wells being as far as Nashville, Howard County, 12 miles from the mountains, and as far as southern Dallas County, 30 miles from the mountains. The following brief notes describe the pre-Cretaceous rocks that have been found in three wells.

The Dudley *et al.* Owen No. 1, in Sec. 27, T. 10 S., R. 16 W., southern Dallas County, reached Paleozoic quartzite, a sample of which was examined by Miser in 1923. The driller's log indicates that the quartzite was struck at a depth of 2,238 feet and was penetrated for only ½ foot before the well was abandoned.

[1]C. W. Honess, "Geology of Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties, Oklahoma," *Oklahoma Geol. Survey Bull. 40-R* (1927), p. 28.
Sidney Powers, "Age of the Folding of the Oklahoma Mountains," *Bull. Geol. Soc. Amer.*, Vol. 39 (1928), p. 1045, footnote.

The Eagle Lumber Company's well No. 1 of West, Peterson and Latimer, at the northeast corner of the NE. ¼, SW. ¼, Sec. 12, T. 10 S., R. 16 W., southern Dallas County, reached Paleozoic quartzite or quartzitic sandstone at a depth of about 2,240 feet. A sample of the quartzite from this depth was examined by Miser in 1923.

The Perpetual Oil and Gas Company's well (elevation, 358 feet) at Nashville, Howard County, encountered Paleozoic rocks at a depth of 1,260 feet and was drilled into them for a distance of 20 feet. The cuttings, which were examined by Miser in 1916, consisted of hard black shale, hard sandstone, and much pyrite. They seem to be Carboniferous.[1]

WELLS IN SOUTHEASTERN OKLAHOMA

Many wells in the Coastal Plain of southeastern Oklahoma seem to have reached basement rocks, if the depth and the logs are indicative, but only a few seem to have provided cuttings that have been examined by geologists. Notes on some of the wells are here given.

The Bokhoma well, at the northwest corner of the NW. ¼, SE. ¼, Sec. 15, T. 8 S., R. 26 E., 2 miles north of Bokhoma, McCurtain County, Oklahoma, entered Paleozoic rocks at a depth of about 2,040 feet and continued in them until the hole was abandoned at a depth of 2,340 feet. C. W. Honess,[2] who saw some of the cuttings, states that they are Paleozoic.

The Louisiana Petroleum Company's well, in Sec. 1, T. 7 S., R. 22 E., McCurtain County, Oklahoma, according to the log,[3] seems to have passed through the Trinity sand at a depth of 515 feet and to have continued to the bottom of the hole, 1,151 feet, in an alternating sequence of Paleozoic shale and sandstone, which are assigned to the Carboniferous by the authors cited. At the time they wrote the report the large area of pre-Carboniferous rocks that adjoins the Coastal Plain several miles north of the Louisiana Petroleum Company's well was not generally known and had not been described or even mentioned in print, and it was generally believed that all the Paleozoic rocks in this part of Oklahoma were Carboniferous. The writers believe that no more exact age designation than Paleozoic for the basement strata in the well is justi-

[1]H. D. Miser and A. H. Purdue, "Asphalt Deposits and Oil Conditions in Southwestern Arkansas," *U. S. Geol. Survey Bull. 691* (1919), p. 290.

[2]Oral communication, 1923.

[3]C. W. Shannon and others, "Petroleum and Natural Gas in Oklahoma," *Oklahoma Geol. Survey Bull. 19*, Pt. 2 (1917), pp. 326-27.

fied, because shale and sandstone occur in the Ordovician as well as in the Carboniferous.

The Oklahoma-Colorado Oil and Gas Company's well No. 1, in Sec. 7, T. 6 S., R. 19 E., 3 miles northeast of Sawyer, Choctaw County, Oklahoma, passed directly out of the Trinity formation into the Stanley shale (Mississippian) at a depth of 595 feet and remained in this formation to the bottom of the well, which was 4,970 feet deep. Cuttings of the Stanley, obtained at various depths from 2,130 to 3,966 feet, were examined in 1919 by K. C. Heald, M. I. Goldman, and H. D. Miser, and were found to consist of hard quartzitic sandstone, black shale, and limy sandstone. The cuttings revealed the presence of slickensides and brecciated material. They are here described.

PALEOZOIC ROCKS IN OKLAHOMA-COLORADO OIL AND GAS COMPANY'S WELL NO. 1 IN SEC. 7, T. 6 S., R. 19 E., 3 MILES NORTHEAST OF SAWYER, CHOCTAW COUNTY, OKLAHOMA

(Churn drill was used to about 2,200 feet and core drill below this depth)	*Depth in Feet*
Quartz sand grains, black shale, calcareous material, and pyrite; examined by H. D. Miser	2,130
Sand grains, black shale, and calcareous material; examined by H. D. Miser.	2,158
Sand grains, black shale, and calcareous material; examined by H. D. Miser.	2,175
Brown sand; examined by H. D. Miser	2,180-2,200
Sample is a core of greenish gray fine-grained sandstone; examined by H. D. Miser	2,200
Black shale showing slickensides; examined by H. D. Miser	2,235
M. I. Goldman and K. C. Heald report as follows on four samples (depth not given).	
"One sample is an indurated shale, which has, however, no slaty cleavage. A second is shale with bands of a material which has not yet been determined. A third plainly comes from a fault zone and shows a brecciated contact between shale and limestone. The fourth is a very limy sandstone. The beds evidently stand at a considerable angle to the direction in which the bit is cutting"	(?)
Sandstone; a thin section examined by P. V. Roundy revealed "incipient schistosity with parallel banding of quartz and dark minerals"	3,966

The Trojan Home Builders' Nash well, drilled in 1920 in the NW. ¼, Sec. 8, T. 4 S., R. 15 E., Pushmataha County, Oklahoma, entered the Jackfork sandstone at a depth of less than 100 feet.[1]

The Gillam and Foster Company's Wade No. 1, in Sec. 13, T. 6 S., R. 14 E., Choctaw County, Oklahoma, passed from the Trinity

[1]Information supplied orally by S. J. Monahan, of Antlers, Oklahoma.

formation into the Jackfork sandstone at a depth of about 982 feet, and remained in this sandstone to a depth of 2,510 feet, the bottom of the hole.

WELLS IN NORTHEASTERN TEXAS

Several wells have been drilled into Paleozoic rocks in northeastern Texas east of Denison, Grayson County. Perhaps there are others that are not known to us. The wells that are described in the following notes were drilled in Red River, Lamar, Fannin, and Grayson counties.

The Lady Alice No. 1, drilled by the Johnston Petroleum Syndicate in search of oil at Silver City, 3/4 mile south of Red River and 18 miles north of Clarksville, passed through the gently southward-dipping Trinity formation (Lower Cretaceous) into Paleozoic rocks at a depth of 1,673 feet, and remained in them to the bottom of the well, which is 4,520 feet deep. The well thus passed through 2,847 feet of Paleozoic rocks. Many cuttings were submitted in 1924 by J. Fred Johnston, of Clarksville, Texas, to the United States Geological Survey and were examined by H. D. Miser. Other cuttings were submitted to the Texas Bureau of Economic Geology and were examined by E. H. Sellards, T. L. Bailey, and R. T. Short. The cuttings consist of shale with some interbedded limestone and sandstone. The shale is bluish black to black, shows shiny surfaces, and has been metamorphosed, some having been changed to slate and some to phyllite. Much of the shale is papery and shows minute crumpling. The sandstone is gray, and some of it is quartzitic. The limestone is gray and sandy. White quartz and calcite are plentiful in many of the samples and probably occur as veins in the shale, sandstone, and limestone. Pyrite is present in many of the cuttings. A sample from this well at the depth of 1,763-1,767 feet is described by T. L. Bailey as follows.

> The sample consists of cuttings of shiny slate-gray phyllite. This rock is distinctly metamorphosed, being midway in degree of metamorphism between slate and schist. The schistosity planes give a smooth clean appearance like those of slate, but under the microscope they show a slight waviness like the waviness seen in schists. Thin sections were made of this phyllite, both at right angles and parallel to the schistosity. These sections show the rock to be completely recrystallized. It is composed principally of the minerals quartz and biotite. The biotite flakes show a wavy cross section and are arranged in closely spaced laminae or fine bands. The biotite is so abundant that the cross section of the rock shows a very plain pleochroism or change of color from pale brownish yellow to dark brown. The quartz grains are distinctly elongated parallel to the schistosity, some having an "augen" or lens-like shape, due to pressure. All the crystals in this rock are small. A good many muscovite flakes are also present. The phyllite was apparently a dark shale

before it was metamorphosed. Several fragments of fine-grained metamorphosed vein quartz or chert are present in the sample in addition to the phyllite. There are hematite streaks in the quartz which show a distinct parallel orientation due to metamorphism. This quartz is fine-grained. In the washed material from a ground-up sample several angular grains of quartz, probably from quartz veins in the phyllite, and a few octahedral crystals of pyrite are present.

The cuttings of Paleozoic rocks from the Lady Alice well No. 1 are comparable in lithologic character with the Womble shale, Blakely sandstone, and Mazarn shale, of Ordovician age, the Crystal Mountain sandstone, of Ordovician (?) age, and the Collier shale, of Cambrian age—all of which are exposed in the part of the Ouachita Mountains adjacent to the Coastal Plain in southeastern Oklahoma. Thus the Paleozoic rocks in this well are either Cambrian or Ordovician.

The Bailey Development Company's Ford well No. 1, 14 miles north-northwest of Paris, Lamar County, was drilled to a total depth of about 1,900 feet. Cuttings from 1,575 to 1,750 feet were received and examined at the Texas Bureau of Economic Geology and were identified as Cretaceous. C. L. Baker[1] has furnished descriptions of cuttings between 1,777 and 1,880 feet, and from them Miser concludes that the rocks penetrated between these depths are Cretaceous. The basement rocks were reached at a depth of 1,880 feet, and cuttings below this depth were examined by the Texas Bureau of Economic Geology and by Miser. Their lithologic character indicates that the rocks belong either to the Stanley shale (Mississippian) or to some shale and quartzite formation of Ordovician age. The exposed Ordovician formations that contain shale and quartzite in the Ouachita Mountains are the Crystal Mountain sandstone, Mazarn shale, Blakely sandstone, and Womble shale.

The Elkay Oil Company's well No. 1, on the Wilson Lane farm, 2 miles northwest of Ector, Fannin County, penetrated the basement rocks of the Coastal Plain. Many cuttings were sent in 1921 to the United States Geological Survey and also to the Texas Bureau of Economic Geology; they were examined by Miser, Sellards, and Waite. The cuttings received by the United States Geological Survey indicate that the drill passed from the Trinity formation into the Paleozoic rocks at a depth of 2,380 feet, though there is a possibility, as suggested by

[1]Letter to H. D. Miser dated January 24, 1930.

PALEOZOIC ROCKS FROM THE BAILEY DEVELOPMENT COMPANY'S FORD WELL NO. 1, LAMAR COUNTY, TEXAS

(Descriptions by E. H. Sellards and Dabney Petty)

	Depth in Feet
Mixed cuttings of limestone and quartzitic sandstone. The limestone evidently comes from above and the sandstone from this depth. This quartzitic sandstone is dark gray, and the siliceous cement is as hard as the sand grains. The grains, for the most part, preserve their original shape and do not exhibit the mosaic texture seen in well metamorphosed quartzite. However, several needles of pale green actinolite which seem to have formed after the deposition of the rock and which apparently partly penetrate grains of quartz are noted. The occurrence of this actinolite suggests that the rock has been subjected to considerable pressure and is probably very old. Most of the grains in this quartzitic sandstone are composed of quartz, but some feldspar and hornblende are present. A large amount of chloritic material is present in the cement, and this also suggests some metamorphism	1,880-1,900
Cuttings of rather hard black slaty shale and dark gray quartzitic sandstone. The quartzitic sandstone is similar to that at 1,880-1,900 feet. The black shale or slate shows many flakes, apparently of graphite, on the cleavage surfaces, and the thin section of this shale also shows many black opaque flakes scattered through the fine sand and finely crystalline argillaceous material which constitutes most of the rock. The occurrence of these graphite (?) flakes shows that the rock has undergone metamorphism. No fossils noted	1,900-?

the presence of fine-grained bituminous sandstone among cuttings in the possession of the Bureau of Economic Geology, that the drill passed into the Paleozoic rocks at or near a depth of 2,338 feet. The cuttings of Paleozoic rocks extending to a depth of 3,134 feet consisted of interbedded shale and sandstone. The shale is bluish black to black and splits into thin layers; some of it is micaceous and some is slightly calcareous; slickensides and veinlets of white calcite were noted. Sponge spicules were seen by Waite in some samples. The sandstone is hard, gray, fine-grained, and quartzitic, and some of it is slightly calcareous. The lithologic character of the cuttings, as determined from their review in October, 1930, by Miser, led him to conclude that the Paleozoic cuttings are from the Stanley shale.

A well that entered basement rocks was drilled in 1930 by George L. Pace for E. V. Parsons on the Eli Morgan farm, J. C. English Survey, near Savoy, in the western part of Fannin County. Cores from depths of 2,794- 3,048 feet were received by the Bureau of Economic Geology. The driller's log indicates that the base of the Cretaceous in this well is probably near 2,280 feet. The rocks are described as follows.

PALEOZOIC ROCKS IN PARSONS WELL, ON MORGAN FARM, NEAR SAVOY, TEXAS
(Description of cores by E. H. Sellards)

	Depth in Feet
Very hard non-calcareous gray sandstone, well cemented and quartzitic. The rock is nearly pure quartz sand with a few minute particles of a dark mineral and a green mineral	2,794
Hard grayish shale	2,802
Fine-grained dark gray quartzitic sandstone	2,999
Non-calcareous black shale or siltstone. In thin section the rock is seen to be made up chiefly of minute particles with a few very small sand grains and dark, possibly asphaltic inclusions	3,042
Non-calcareous gray quartzitic sandstone traversed by a thin calcite vein	3,045
Fine dark gray quartzitic sandstone; shows slickensidings	3,048

No samples were obtained in the interval from 2,280 to 2,794 feet. As nearly as can be judged by the driller's log, the rock of this interval is in the main similar to that represented by the cores described. To Miser, who also examined the previously described samples, their lithology suggests that they are from the Stanley shale.

The Peter Oils, Inc., well No. 1, Butcher lease, 2½ miles east of Denison, Grayson County, passed from the Trinity formation into the basement rocks, which the driller's log indicates were reached at a depth of about 1,511 feet. Many cuttings of the basement rocks from depths ranging from 1,815 to 4,023 feet were submitted in 1922 to the Texas Bureau of Economic Geology and were examined by J. A. Udden and E. H. Sellards. Also many cuttings from various depths between 2,535 and 4,023 feet were submitted in the same year to the United States Geological Survey and were examined by K. C. Heald and P. V. Roundy.

The cuttings as they are described in the notes by these geologists include (1) gray sandstone, much of which is slightly calcareous; (2) bluish gray and black shale with some dark gray shale, mostly non-calcareous, many samples showing slickensides, some samples of slate-like hardness splitting into thin, sharp fragments; (3) a little gray and brown limestone; (4) two samples showing cone-in-cone structure; and (5) calcite, with some quartz, in many samples, occurring as veins in shale and sandstone. The shale and sandstone are interbedded, and both are represented in most of the cuttings.

Udden makes the comment that the shale in these cuttings is harder than the ordinary shale in the Pennsylvanian and somewhat resembles the supposed pre-Cambrian schist-like shales from wells northeast of the Central Mineral region. These schist-like shales are now

placed in the Paleozoic by the writers. Udden also calls attention to the resemblance of the vein-bearing sandstone from the well to the veined quartzitic rock which has been observed in several other wells in north-central Texas and which at that time was suspected of belonging below the Paleozoic, but he states that the samples have a Pennsylvanian aspect.

Heald and Roundy suggested that the cuttings may have come from the Atoka formation, Jackfork sandstone, or Stanley shale (the Atoka being of Pennsylvanian age and the other two Mississippian), but they mentioned the resemblance of the cuttings to parts of the Glenn formation (Pennsylvanian).

To Miser the lithologic character of the cuttings, which he reviewed in October, 1930, corresponds with that of the Stanley shale and not with that of any of the other formations in regions adjacent to the Coastal Plain in Texas and Oklahoma. He thus concludes that they are from the Stanley shale.

The J. A. O'Dell well, on the T. R. Shannon Survey, 2 miles southeast of Denison, entered Paleozoic rocks. From an examination of cuttings in the possession of the Bureau of Economic Geology, Miser believes that the Paleozoic rocks possibly belong to the Missouri Mountain shale, of Silurian age, and the Polk Creek shale, of Ordovician age. The deepest available sample from the Trinity formation came from a depth of about 1,547 feet, and the highest available sample from the Paleozoic came from a depth of 1,580-1,587 feet. The drill thus passed from the Trinity into the Paleozoic at a depth between 1,547 and 1,580 feet. Descriptions of the Paleozoic cuttings are here given.

Paleozoic Rocks in J. A. O'Dell Well, 2 Miles Southeast of Denison, Texas
(Descriptions by H. D. Miser and E. H. Sellards)

	Depth in Feet
Splintery shale; mostly red, but some fragments buff and some black	1,580-1,587
Shale like that just described, with a small amount of quartzite	1,593-1,596
Shale in fragments of many colors—brown, green, red, yellow, and black	1,750
Bluish shale with some fragments of buff and red shale	1,780
Red and buff shale with nearly equal amount of black shale; slickensides	1,825
Reddish brown and hard black shale; slickensides	1,865
Reddish brown and hard black shale in equal amounts	1,860-1,880
Reddish brown and hard black shale	1,890-1,900
Hard black shale, some jasper, and some brown shale	1,945

The Preston well No. 1, Munson lease, 2 miles north of Denison, penetrated Carboniferous rocks after passing through the Lower Cretaceous. Cuttings from several depths ranging from 3,140 to 3,260 feet were examined in 1922 by K. C. Heald. They consisted of dark gray to

black shale and gray sandstone whose general character suggested to Heald their resemblance to the shale and sandstone of the Stanley shale of the Ouachita Mountains.

PALEOZOIC ROCKS IN PRESTON WELL NO. 1, MUNSON LEASE, 2 MILES NORTH OF DENISON, TEXAS

(Description of cuttings by K. C. Heald)

	Depth in Feet
Black shale and gray sandstone. The shale is smooth, does not show fissility, and contains no fossils. The sand is extremely fine-grained, clear quartz, not very well rounded. Cementing material contains a little lime. When heated, gave a distinct indication of oil and a smell of ammonia. One grain of rose quartz and two green grains seen	3,140
Same as sample from 3,140 feet except that percentage of sand is greater. Also the sand seems to be stained with dark material which did not prove to be oil, although tested with both heat and chloroform. Sample 60 per cent or more sand	3,147
Gray to black shale; siliceous, very compact; scratches steel. Also some sandstone, light gray, very fine-grained, very compact. Sandstone grains are angular, fairly uniform in size, the largest about 0.25 millimeter in greatest dimension. Percentage of sand about 60	3,180
Shale, black, dense, non-calcareous. Very strong development of platy minerals, which may mean incipient schistosity, but direction of bedding plane could not be proved. Fragments cut steel. In the sand there are some long acicular glistening black crystals	3,250
Same as 3,250	3,260

The Peter Oils, Inc., Preston well No. 2, Munson farm, 2½ miles north of Denison, passed from the Cretaceous rocks into Paleozoic rocks. Cuttings from depths ranging from 2,370 to 3,260 feet were submitted in 1922 by H. A. Jones of the company, to the Bureau of Economic Geology. As determined by Miser, who examined them in October, 1930, they consist of interbedded shale and sandstone. The shale is bluish gray, dark gray, and black, is hard, and breaks into splintery fragments. The sandstone is fine-grained, quartzitic, and light to dark gray. From the lithology of the cuttings Miser concludes that they came from the Stanley shale.

The G. L. Blackford well No. 1, drilled by W. B. Munson on the Blackford farm, seems from available information to be near the Preston well No. 2. It is reported to have a depth of 2,210 feet. From the driller's log the writers are unable to determine the age of the rocks below the Trinity sand other than that they are Paleozoic. In the discussion of this well, Hopkins, Powers, and Robinson[1] state that a part of the

[1] O. B. Hopkins, Sidney Powers, and H. M. Robinson, "The Structure of the Madill-Denison Area, Oklahoma and Texas, with Notes on Oil and Gas Development," *U. S. Geol. Survey Bull.* 736 (1923), p. 21 and Pl. 5.

Paleozoic rocks "is probably Caney shale" and that higher beds "may belong to the Glenn formation." These suggested age assignments are evidently based on the driller's log.

The J. L. Campbell well No. 1, 6 miles north of Pottsboro, which was begun by J. T. Bryant and later taken over by the Lone Star Gas Company, was drilled to a depth of 2,455 feet.[1] The driller's log indicates that Paleozoic rocks were penetrated below the Trinity sand, but from the log it is not possible to make a more definite age assignment.

The Simpson-Fell Oil Company's Wall well No. 1, in the Pottsboro gas field, 6 miles west of Denison, passed out of the Cretaceous into Paleozoic rocks at a depth of about 900 feet and remained in Paleozoic rocks to a depth of 2,515 feet, where drilling was discontinued. The productive gas sand in the well, which is reported to have had an initial daily output of 10,000,000 cubic feet in 1927, occurs at a depth of 847 to 850 feet and is thus near the base of the Trinity sand. The cuttings from 900 to 1,552 feet consist of flint, calcareous chert, siliceous limestone, and some shale; and the cuttings from 1,552 feet to the bottom of the well at 2,515 feet consist of shale. Thus, they may be grouped in two units, the upper consisting predominantly of flint, chert, and limestone, and the lower consisting of shale. On the basis of lithology some geologists have thought the upper unit to be the Wapanucka limestone and the lower unit the Caney shale, both of Carboniferous age. So far as the writers know, the first fossil evidence on which an age assignment could be made was discovered by Maynard P. White,[2] who found graptolites of Ordovician age in the shale unit. He also called attention to the lithologic similarity of the upper unit to the Talihina chert of southeastern Oklahoma. White's correlations have been corroborated by Miser, who examined, in October, 1930, a complete set of cuttings that are in the possession of the Bureau of Economic Geology. The upper unit Miser assigns to the Bigfork chert, a formation of Ordovician age which is widely exposed in the Ouachita Mountains of Arkansas and Oklahoma and which constitutes a part of the Talihina chert of the Oklahoma part of the mountains. The lower unit Miser assigns to the Stringtown shale, a formation of Ordovician age.

The chert of the Bigfork, as shown by the samples from the Wall well No. 1, is dark gray to brownish gray, is laminated, and contains some sponge spicules and linguloid shells. The flint is waxy in appear-

[1]O. B. Hopkins, Sidney Powers, and H. M. Robinson, *op. cit.* (1923), p. 20 and Pl. 5.

[2]Oral communication to H. D. Miser and letter to E. H. Sellards, 1930.

ance, breaks with a conchoidal fracture, and is light to dark gray and brownish black. Some of the larger fragments show minute fracturing. The limestone contains a large proportion of fine-grained silica and presumably grades into chert. It is laminated like the chert and is mostly dark gray, though some is mottled light and dark gray. The shale is black, olive-green, and greenish gray; some samples show slickensides, and some are sufficiently hard to break with a splintery fracture.

Most of the Stringtown shale, underlying the Bigfork chert in the Wall well No. 1, is greenish gray, but some of it is gray, and much of the upper part is black. Vein calcite occurs in a few samples. The shale is soft and breaks into thin fragments, which have been worn and rounded during the drilling of the well. Some of it shows slickensides. By splitting the shale fragments Miser found a few linguloid shells and at depths ranging from 1,835 to 2,435 feet, small parts of graptolites. E. O. Ulrich, who has examined the fragmentary graptolite material, has identified *Dicellograptus* of a type that is found in the Normanskill shale fauna—the fauna which is present in the Stringtown shale. This fauna is also present in the Womble shale. Both the Stringtown and Womble shales are widely exposed in the Ouachita Mountains of Arkansas and Oklahoma.

The Westover *et al.* Easton well No. 1, on Survey 443, 9 miles northwest of Denison, entered Paleozoic rocks beneath the Cretaceous. From a core which Sellards examined in 1920, he concludes that the material is from the Stanley shale. His description of the core is as follows.

The sample includes three parts of an 8-inch core from a depth of 1,015 feet. The first pieces received (of the uppermost part of the core?) were about 6 inches in length and were sandstone, although included with the sandstone was a considerable quantity of black shale. Another piece including about 9 inches of the core was subsequently submitted. This piece also is mostly sandstone, but shows the contact between the sandstone and the shale. This contact plane dips at an angle between 55° and 60° from the horizontal. A third piece of the core received is still within the core barrel. It includes 6 or 7 inches of the core and is mostly shale.

The sandstone of this core is gray, medium fine-grained, and in places very slightly calcareous. In thin sections it is seen that the sand grains are of varying sizes and shapes, some being angular and others rounded. Within the sandstone are many inclusions of shale, ranging in size from very small fragments to pieces an inch or more in length and of varying width. In the sandstone also are found inclusions of coaly material such as might have been left from plant fragments. However, both plant texture and structure are wanting, and these fragments must be regarded as indeterminate. No fossils were found in either the sandstone or the shale. A few minute light-colored veins, probably of calcite, traverse the sandstone.

ROCKS UNDERLYING CRETACEOUS IN BALCONES FAULT ZONE OF CENTRAL TEXAS[1]

E. H. SELLARDS[2]
Austin, Texas

ABSTRACT

Underlying the Cretaceous in the Balcones fault zone of central Texas are sediments consisting chiefly of shales and sandstones which are somewhat altered and are only sparingly fossiliferous. On the basis of fossils obtained from one of the wells, together with the general appearance of the shales and sandstones, the sediments are believed to be largely of Paleozoic age. They are regarded as having accumulated in a trough or syncline in front of the land mass Llanoria, this trough being continuous toward the northeast with the Ouachita Mountains of Oklahoma and westward with the Marathon uplift of Trans-Pecos Texas.

The surface formations in the Balcones fault zone of central Texas are of Cretaceous or later age. However, from well cores and cuttings, it is now known that underneath the Cretaceous in this zone are Paleozoic formations, in general similar to those of the Ouachita Mountains of Oklahoma. Rocks of this character are believed to underlie the Cretaceous in Texas in a relatively narrow belt extending from the Ouachita region of Oklahoma southward to San Antonio and thence westward to the Marathon region of Trans-Pecos Texas. Where exposed in the Ouachita and Marathon regions, these Paleozoic formations are much faulted and folded and somewhat altered. The rocks of this character under the Cretaceous are likewise more or less altered and many are found also to be crushed and minutely faulted. Cores taken from wells in this zone indicate at several localities steeply dipping and closely folded rocks. The wells, after passing through the Cretaceous in this zone, enter Paleozoics with no indicated regularity in regional distribution of the formations. It is believed, therefore, that the rocks in this narrow belt under the Cretaceous through central Texas are folded and

[1]Read before the Association at the New Orleans meeting, March 20, 1930. Manuscript received, March 6, 1931.

[2]Associate director, Bureau of Economic Geology, University of Texas.

thrust much as are those of the Marathon and Ouachita regions.[1] The counties in and near the Balcones zone in central Texas in which these rocks are known and to which this paper relates are Bell, Bexar, Caldwell, Dallas, Ellis, Falls, Hays, Hill, Kendall, McLennan, Medina, Travis, and Williamson. Westward from this region this belt of Paleozoic formations is believed to extend through Kinney, Val Verde, and Terrell counties to the Marathon region.[2] Northward in Texas this belt of rocks passes through Grayson, Fannin, Lamar, and Red River counties. These Paleozoic formations are believed to have accumulated in a trough or syncline in front of the land mass Llanoria.

In central Texas westward and northwestward from the Balcones fault zone is found a Paleozoic section of foreland facies including formations of nearly the same age as those found in the syncline, but of different character. The formations of the foreland consist of sandstones, shales, and heavy limestones, and those of the syncline consist largely of quartzitic sandstones, shales, and chert with relatively little limestone.

The western margin of these rocks of synclinal facies is sharply marked and in central Texas is believed to be approximately as indicated on the map (Fig. 1). The eastern margin, however, is imperfectly known. Wells in the Luling oil field in Caldwell County indicate that the Cretaceous at that place rests directly on schist, probably of pre-Cambrian age. These wells accordingly may be east of the syncline in which Paleozoic sediments were deposited, although it is also possible that the Paleozoic formations may have been removed at this spot previous to Cretaceous deposition. Another locality at which Cretaceous rests on schist, probably of pre-Cambrian age, is reported by C. L. Baker as occurring near the Rio Grande in Mexico, south of the Marathon region.[3] Wells in Mexico west of Del Rio terminated in arkosic material, probably of Cretaceous age, indicating the existence near by of granitic land masses. Though the eastern margin of the synclinal belt of the

[1]For a discussion of the probable southward extension of these Paleozoics of Ouachita facies, see the following papers.

M. G. Cheney, "History of the Carboniferous Sediments of the Mid-Continent Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 6 (June, 1929), pp. 557-94; Stratigraphic and Structural Studies in North-Central Texas, *Texas Univ. Bull. 2913* (1929).

E. H. Sellards, "Preliminary Map of Underground Position of pre-Cambrian in Texas," *Texas Bur. Econ. Geol. Cir. 8* (1929).

Hugh D. Miser and E. H. Sellards, "Pre-Cretaceous Rock Found in Wells in the Part of the Gulf Coastal Plain South of the Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, this number, pp. 801-18.

[2]Wells of Kinney, Val Verde, and Terrell counties will subsequently be described.

[3]Letter of October 20, 1930.

Paleozoic is thus doubtfully determined, it seems probable that these formations accumulated in a trough lying in front of land masses in Texas and northern Mexico.

The following list includes wells in this zone in central Texas from which cores or cuttings have been examined. A few other wells have been drilled into these formations, but only those from which samples have been obtained are used in determining the character of the rock.

TABLE I

DATA ON WELLS ENTERING PRE-CRETACEOUS IN CENTRAL TEXAS

Name and Location of Well	*Total Depth in Feet*	*Depth in Feet to Paleozoic*	*Kind of Rock*
BELL COUNTY*			
Nolan Bell Company's Bacon 2, 3.9 mi. W. of Nolanville	1,820	896	Black shale
Mellon Oil Company's Bailey 1, Evitts Survey, 7 mi. S., 4 mi. E. of Killeen	3,790	798	Black shale and novaculite
Winans *et al.* Ferguson 1, James Bowers Survey, 7 mi. NW. of Belton	1,780	821±	Black shale, gray quartzitic sandstone
Rio Grande Oil Company's D. W. Hair 1, 2¼ mi. NW. of Belton	2,002	1,157	Black shale, gray quartzitic sandstone
Bell County Oil Company's Holcomb 1, Walker Survey, 3 mi. W. of Belton	1,640	1,107	Quartzitic sandstone
Eclipse Oil Company's Slayden 2, 7 mi. S. of Killeen	1,216	1,000±	Dark shale and chert
Bell Williams Oil Company's Warrick 1, Ingram Survey, 6.7 mi. NW. of Jarrell	1,373	†	Dark shale and quartzitic sandstone
J. B. Hartman's Warrick 1, Webb Survey, 6.8 mi. NW. of Jarrell	2,772	973	Dark shale and quartzitic sandstone
BEXAR COUNTY			
U. S. Goverment's Camp Bullis	1,910	1,799	Altered shale
U. S. Goverment's Leon Springs	2,500	1,015‡	Altered shale

*Several other wells in western Bell County have been drilled through the Cretaceous. *Texas Univ. Bull. 3016* (1930), p. 86. For description of samples from these wells see *Bur. Econ. Geol. Cir. 6* (1928).

†Base of Cretaceous not definitely determined. Samples examined from depths ranging from 1,190 to 1,373 feet.

‡For a more detailed account of this well see "Observations on Two Deep Borings near the Balcones Faults," by J. A. Udden, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1919), pp. 124-31. Udden compares the rock from this well below the Cretaceous with the Millican formation, probably pre-Cambrian, of the Van Horn region. He recognizes, however, that Paleozoic rocks in this faulted belt might be metamorphosed as in these samples.

TABLE I—*Continued*

DATA ON WELLS ENTERING PRE-CRETACEOUS IN CENTRAL TEXAS

Name and Location of Well	*Total Depth in Feet*	*Depth in Feet to Paleozoic*	*Kind of Rock*
Gas Ridge Syndicate's Pepper 1, 14 mi. W. of San Antonio	3,783	2,864	Altered shale
CALDWELL COUNTY			
United North and South Oil Company's Kelley 1, Reville Survey, Luling Oil Field	7,859	4,728	Schist
United North and South Oil Company's Tabor 8	4,854	4,796	Schist
United North and South Oil Company's Tiller 1	7,504	4,807	Schist
Gulf Coast Drilling Company's Schawe 1, Maxwell	3,445	3,415	Shale
DALLAS COUNTY			
McNeil and Mathews' Seaton 1, 2 mi. NE. of Britton		§	Black shale
ELLIS COUNTY			
Triangle Corporation's Hale 1, 1 mi. S. of Avalon	3,190 Drilling	3,060	Slickensided shale and quartzitic sandstone
FALLS COUNTY			
Humble Oil and Ref. Company's F. Pucek 1, L. Thurmer Survey, 4 mi. from W. and 6½ mi. from S. county line	3,576	3,535	Phyllite
HAYS COUNTY			
E. A. Buckman's Elsner 1, Fowler Survey, 3 mi. S. of Dripping Springs	2,300	688±	Sandstone and black shale
Harley and Whitington's Heidenreich 1, 3 mi. SE. of Kyle	2,767	2,750	Dark schistose shale
HILL COUNTY			
Hillsboro City well	2,152	1,792±	Quartzitic sandstone
Hillsboro City well	1,838	1,794±	Shale and quartzitic sandstone
Hill-Texas Company's Weatherby 1, W. G. Meriweather Survey, 3½ mi. E. of Hillsboro	3,981 Drilling	2,275 ±	Black shale and quartzitic sandstone
KENDALL COUNTY			
Boerne City well, 1 mi. W. of Boerne	1,118	925±	Schistose shale
Permian Oil Company's Bowles 1, 6 mi. NE. of Boerne	1,550	1,195±	Schistose shale

§Depth to Paleozoic not determined. Cores examined from depths of 2,435 and 2,655 feet.

TABLE I—*Continued*

DATA ON WELLS ENTERING PRE-CRETACEOUS IN CENTRAL TEXAS

Name and Location of Well	*Total Depth in Feet*	*Depth in Feet to Paleozoic*	*Kind of Rock*
Abercrombie and Harrison's Kunz 1, J. W. Cormack Survey, 7 mi. N., 1 mi. E. of Boerne........	2,250	1,895±	Schistose shale
McLENNAN COUNTY			
Waco Oil and Ref. Company's Harrington 1, Moore Survey, 4½ mi. N. of Waco..........	3,600	2,600	Quartzitic sandstone and black shale
St. Louis Oil Pool, Stuart 1, Johnson Survey, 2¾ mi. S., ½ mi. E. of McGregor..............	3,512	1,235±	Chert, limestone, and black shale
Hodges *et al.* Lawrence 1, B. C. Waters Survey, near McGregor		1,313	Chert and black shale
MEDINA COUNTY			
California Medina Association's Rothé 1, Sec. 1012, Medina County School Land..........	3,705	‖	Black shale
TRAVIS COUNTY			
Griffith *et al.* Evans 1, 9 mi. SW. of Leander.................	983	620	Quartzite and black shale
E. D. Summerow's Reimer 1, Little Survey..................	1,274	266	Black shale
Cypress Creek Drilling Association's Romberg 1, Miner Survey, on Cypress Creek near Travis County line.................	1,560	¶	Black shale
WILLIAMSON COUNTY			
Donnelly *et al.* Conway 1, Burleson Survey, 7 mi. SW. of Liberty Hill....................	1,133	695	Siliceous limestone and black shale
Georgetown City well..........	1,807	1,260**	Schistose shale
Miller and Mayfield's Miller 1, 3 mi. E. of Liberty Hill.........	1,910	696±	Black shale
Palm Valley Oil Company's Walsh 1, 5½ mi. W. of Round Rock..	1,230	1,230	Novaculite

‖Depth to Paleozoic not determined. Core from 3,560 to 3,565 feet is black shale.

¶Base of Cretaceous not determined, probably near depth of 266 feet as in Reimer 1. Sample examined from depth of 834 feet.

**Exact base of Cretaceous difficult to determine. See J. A. Udden, "Observations on Two Deep Borings Near the Balcones Faults," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1919), pp. 124-31. Depth of 1,260 feet is here used as the probable base because water is reported to have been obtained to that depth. The base of the Cretaceous may be at 1,036 feet or above, or may be somewhat below 1,260 feet. The well was drilled by standard tools and, in the absence of cores, determination of the formations is particularly difficult.

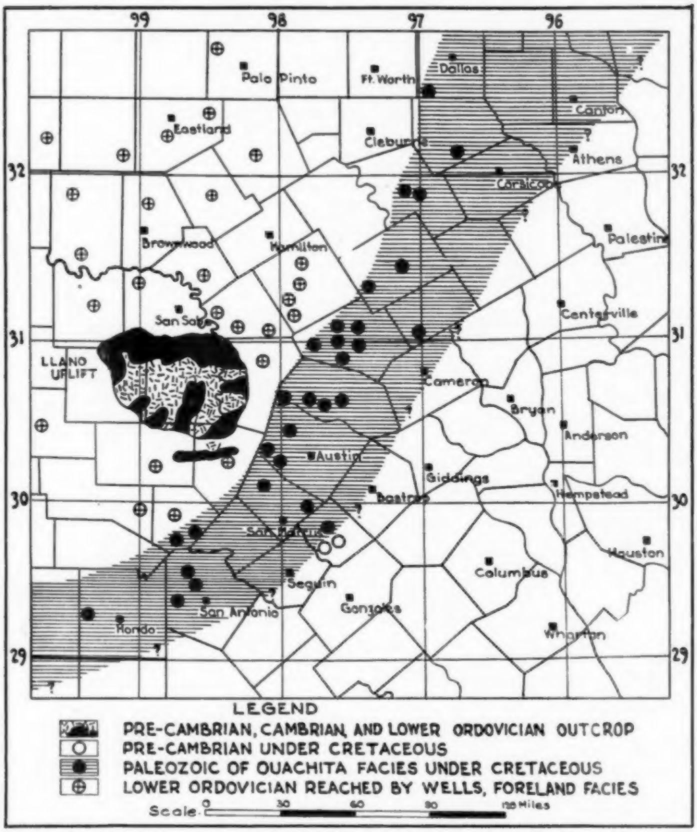


FIG. 1.—Rocks underlying Cretaceous in Balcones fault zone of central Texas.

FORMATIONS RECOGNIZED

Because of the scarcity of fossils the formations underlying the Cretaceous in the Balcones fault zone are difficult to identify. Such determinations of formations as have been made are based principally on the character of the rock and on the probable continuity northeastward to the Ouachita Mountains of Oklahoma, where similar formations are exposed at the surface. In October, 1930, Hugh D. Miser, of the United

States Geological Survey, examined samples from most of these Texas wells in the collection of the Bureau of Economic Geology and many of the formation determinations which follow have been made by him. Miser's intimate acquaintance with the formations of the Ouachita series in Oklahoma lends confidence to his identification of the formations notwithstanding that these identifications, with an exception or two, are made on the basis of lithologic resemblance. As a further check on the identifications, direct comparison was made by Miser, Gould, and Sellards with typical exposures of the various formations in the Ouachita Mountains. However, for several of the wells no determination is ventured at present other than that the formations under the Cretaceous in those wells that have been drilled in this zone in central Texas, with the exception of three wells in the Luling oil field, are probably Paleozoic in age.

Mississippian or early Pennsylvanian.—The section in several of the wells consists of greenish gray quartzitic sandstone alternating with black, commonly slickensided shale. Some inclusions of the shale are found in the sandstone. More than half of the wells enter rocks of this character. These quartzitic sandstones and black shales are lithologically like the Stanley-Jackfork formations of Oklahoma and the rocks in several of the wells are referred provisionally to these formations.

The Evans well in Travis County entered pre-Cretaceous rock at or near a depth of 620 feet. Cores were received from this well at a depth of 789-793 feet. The rock at this depth is black non-calcareous shale alternating with gray quartzitic sandstone. The core shows bedding or cleavage planes of different steepness, the maximum being 70 degrees. The shale is much slickensided and inclusions of the shale are found in the sandstone. The rock is cut by calcite veins and by minute faults.[1] This rock, in the opinion of Miser, represents the Stanley shales. Similar black shales have been found under the Cretaceous in two other Travis County wells as indicated in the list.

The Bailey well in Bell County entered black shales at 860 feet. These shales are regarded by Miser as probably to be correlated with the Stanley. At 2,500 feet this well entered novaculite probably of Devonian age. According to Miser, because of complicated folding, a second horizon of Stanley was evidently encountered between 2,930 and 3,160 feet.

From a well on the Ferguson farm in Bell County, cores were supplied by the operator, J. E. Winans, at intervals, from 1,200 to 1,700

[1]For more detailed description of this core see *Mineral Resources of Texas, Travis County, Texas Univ. Bur. Econ. Geol.* (February, 1930), pp. 45-48.

feet. These cores were prevailingly of non-calcareous black shales and quartzitic sandstone. The rock is cut by calcite veins and the shale shows slickensiding. Two wells drilled on the Warrick ranch in southern Bell County passed through slickensided, black, somewhat schistose shales and greenish quartzitic sandstone from the base of the Cretaceous, at or near 973 feet, to 1,373 feet in one well and to 2,772 feet in another. Other wells from which similar rock was obtained are the Hale well in Ellis County, the Weatherby well in Hill County, the Pepper well in Bexar County, the Harrington well in McLennan County, and the Miller well in Williamson County. All of these wells, as indicated by the character of the rock, probably entered the Stanley-Jackfork formations.

Devonian.—The Bailey well in Bell County entered novaculite at 2,500 feet and terminated in similar rock at 3,800 feet. The novaculite in this well is regarded as probably Devonian, correlating with that of the Ouachita and Marathon regions. Miser's identification of the rock is as follows.

> The samples from this well from depth 2,500 to 3,800 are chiefly, and possibly entirely, novaculite, although it is possible that due to complicated folding the Stanley shale may come into the section at approximately 2,930 to 3,160 feet. The samples immediately under the Cretaceous in this well at 860 and at about 1,900 are regarded as Stanley. The brown shale at 2,640 to 2,655 is not exceptional for the Devonian, since brown shales are found occasionally in the upper part of the novaculite.

Some small undetermined fossils have been obtained from this well at a depth of 3,640-3,650 feet.[1]

In the Slayden well in this county novaculite is found at depths of 935-1,050 feet and underlies what seems to be Silurian found at depths of 710-850 feet. The section in this well is evidently inverted because of overthrust. The dividing line between Silurian and basal Devonian, according to Miser, is somewhat in doubt, but the sample at 935 feet containing some novaculite is taken provisionally as the first (basal) Devonian sample. Samples at 940-945 feet are regarded as Devonian as well as the samples at 950, 1,000, and 1,050 feet. The light-colored novaculite of the lower part of the Devonian is seen in the sample at 950 feet, and below this is the upper member of the novaculite regarded as probably the Woodford chert equivalent. Fossils, including sponge spicules, radiolarians?, and other undetermined small objects of organic

[1]For illustrations of these fossils and additional discussion of the character of the rock see W. S. Adkins, "Geology of Bell County," *Texas Univ. Bull. 3016* (1930).

origin, have been obtained from this rock at depths of 940, 945, and 950 feet.

Silurian ?.—The Slayden well in Bell County at depths of 710-850 feet contains samples which in Miser's opinion suggest Silurian. At greater depths, 935-1,050 feet, the same well contains novaculite suggesting the Devonian, the relations thus indicating an overturned fold. A core obtained from the Pucek well in Falls County, at a depth of 3,535 feet, is lithologically similar to the Missouri mountain slate, Silurian, of the Ouachita section of Oklahoma. The rock in the Elsner well in Hays County, at depths of 725-835 feet, in the opinion of Miser also closely resembles the Missouri mountain slate. This well was drilled to a depth of 2,300 feet and the bottom samples may represent Ordovician, Polk Creek shales.

Ordovician ?.—At a depth of 1,100 feet, the Bacon well in Bell County entered black shale which contained graptolites. These graptolites have been examined by E. O. Ulrich and identified by him as follows.

> One graptolite is sufficiently well exhibited for identification. It is minute and is of a new type. Supposedly it is Ordovician but it might be older or even as high as the base of the Silurian. [1]

The Conway well in Williamson County passes through a section of cherty limestone. On the basis of the lithologic resemblance, this well is regarded by Miser as having entered the Bigfork chert, Ordovician.[2] The Stuart well in McLennan County seems likewise to have entered the Bigfork chert at depths of 1,940-2,440 feet, and below this possibly the Stringtown shale. The Lawrence well in this county contains similar chert.

Pre-Cambrian ?.—Three wells drilled in the Luling oil field in Caldwell County entered schists immediately under the Cretaceous. The maximum penetration into the schists in these wells was 3,131 feet. From the amount of metamorphism in these rocks it is thought that they are probably older than Paleozoic. These wells, as indicated on the map (Fig. 1), are possibly east of the trough in which the Paleozoic sediments accumulated.

[1]For description of samples from this well, see *Texas Univ. Bur. Econ. Geol. Mimeogr. Cir. 6* (1928).

[2]For description of a representative sample of this rock at depths of 962-967 feet, see "Mineral Resources of Texas, Williamson County," *Texas Univ. Bur. Econ. Geol.* (December, 1930), p. 83.

GEOTHERMAL VARIATIONS IN COALINGA AREA FRESNO COUNTY, CALIFORNIA[1]

ANDERS J. CARLSON[2]
Berkeley, California

ABSTRACT

Variations of isothermal elevations with respect to structure are developed from temperature measurements in fifty-six wells of the Coalinga area. The comparative trend of isotherms, geologic strata, and ground surface is shown on two vertical sections through the anticlinal structure of the Eastside field. The results indicate that rock temperatures in this vicinity are controlled chiefly by surface topography and thickness of sediments. Definite correlation between relative temperatures and the oil-bearing structure is not evident.

GENERAL FEATURES

The area under discussion, generally referred to as the Coalinga field, is near the southwest corner of Fresno County, California, on the west side of San Joaquin Valley at the eastern base of the Diablo Range. The productive parts extend approximately 14 miles north and south, and 8 miles east and west. For convenience they may be divided into the Westside field immediately west and north of the town of Coalinga, the Eastside field adjoining this on the northeast, and the Oil City field, a few miles west of the latter.

The predominating exposed rocks are Tertiary and Cretaceous sediments dipping into the valley toward the east and cropping out successively in the Coalinga area and on the mountain slopes north and west. These are underlain by the Franciscan of Jurassic age and overlain in the valleys and lower slopes by the upper Tulare formation and alluvium of the Quaternary.

[1]Read by title before the Association at the San Antonio meeting, March 20, 1931. Manuscript received, March 23, 1931. This paper contains results obtained in an investigation on "Determination of Geothermal Gradients in Oil Fields on Anticlinal Structure," listed as Project No. 25-C of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by the Universal Oil Products Company. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council. Lester C. Uren is director of the project.

[2]Associate professor of petroleum engineering, University of California; junior research fellow, American Petroleum Institute. Introduced by F. H. Lahee.

The Eastside and Oil City fields are situated on an anticlinal nose plunging toward the southeast, and the Westside field on a monocline dipping east. Connecting these productive areas is a synclinal trough with its axis approximately parallel with the anticlinal axis. The extent and relative positions of the structures is evident from the subsurface contours shown on Figure 1.

Oil zones are encountered between the early upper Miocene (Jacalitos) and the Upper Cretaceous (Chico). The most productive are those in the lower Miocene (Temblor) and at the base of the early upper Miocene (Jacalitos). Oil zone *B*, as designated by Arnold and Anderson,[1] represents the top zone of the Vaqueros (Temblor) in the Eastside field and the lowest zone of the Jacalitos in the Westside field. Contours representing the top of the Kreyenhagen (Oligocene) shale, as developed by Wilhelm,[2] are shown in Figure 1. This shale directly underlies the Temblor and marks the lower limit of the productive strata. The shallow production in the Oil City field is derived chiefly from the Chico zone of the Upper Cretaceous.

GEOTHERMAL DATA

Present conditions in this area are favorable for the measurement of well temperatures. In the Eastside field most of the wells are shut in and have been idle for several years. The Westside field is being pumped, and here only relatively few wells are suitable for tests.

The available data have been obtained from 50 wells recently measured by the writer and 6 wells previously measured by C. E. Van Orstrand.[3] Of these, 44 are located in the Eastside field and 12 in the Westside field, as shown in Figure 1. They are identified by serial numbers in the order of their measurement, wells 1-6 being those measured by Van Orstrand. Table I shows a classification of the wells with respect to type and period of idleness previous to measurement.

The only disturbing factor of apparent importance is the evolution of gas. Abnormal temperatures caused by small gas flows are evident in several wells. In a few wells circulation of water is seemingly

[1] Ralph Arnold and Robert Anderson, "Geology and Oil Resources of the Coalinga District, California," *U. S. Geol. Survey Bull. 398* (1910).

[2] V. H. Wilhelm, "The Possibility of Deeper Production in the Coalinga Field, California," *Oil Bulletin* (July, 1927), pp. 695-99.

[3] C. E. Van Orstrand, "Some Evidence on the Variation of Temperature with Geologic Structure in California and Wyoming Oil Districts," *Econ. Geol.*, Vol. 21 (1926), No. 2.

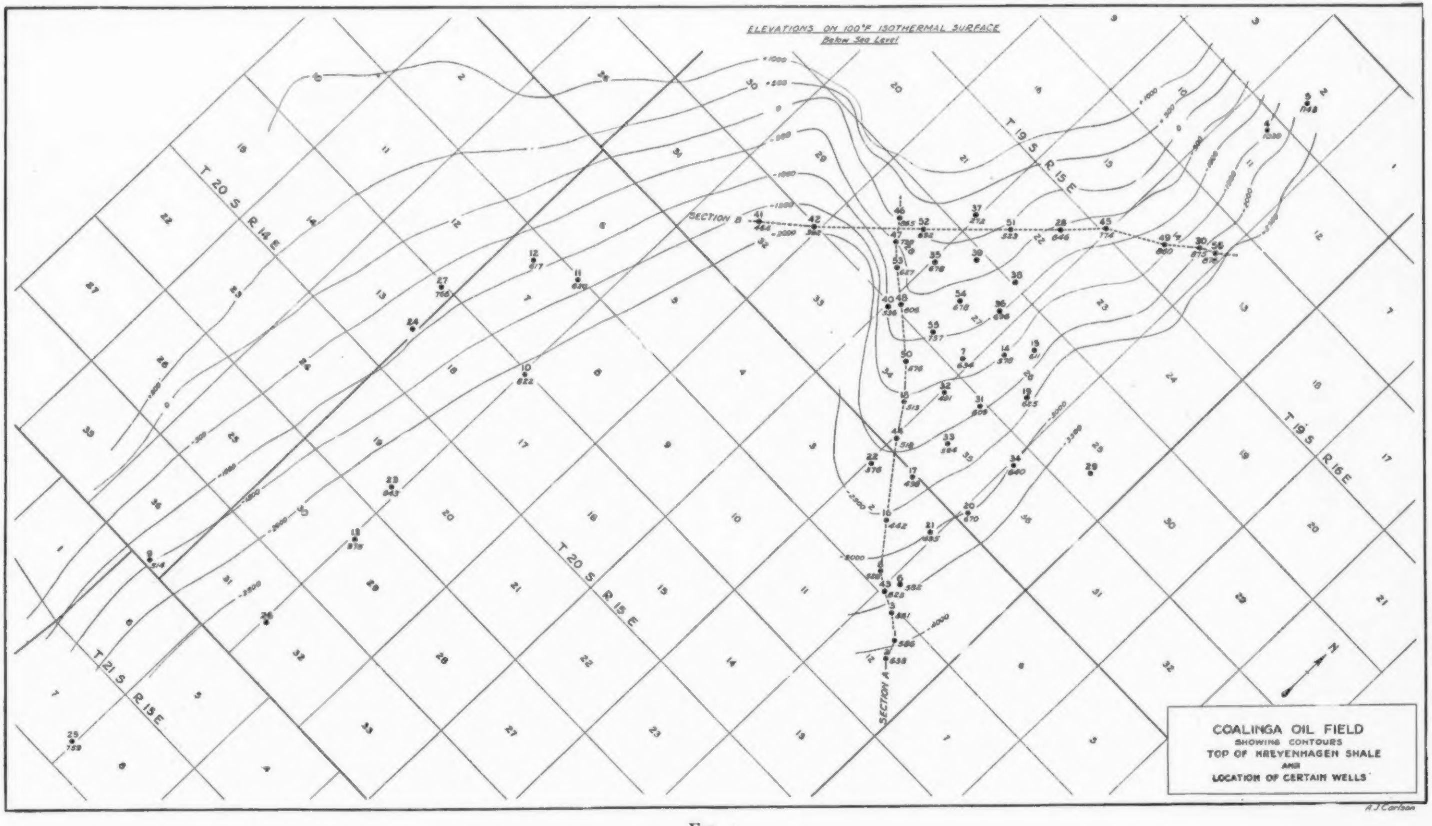

ELEVATIONS ON 100°F ISOTHERMAL SURFACE
Below Sea Level
COALINGA OIL FIELD
SHOWING CONTOURS
TOP OF KREYENHAGEN SHALE
AND
LOCATION OF CERTAIN WELLS
T 19 S R 15 E
T 19 S R 16 E
T 20 S R 14 E
T 20 S R 15 E
T 21 S R 15 E
SECTION A
SECTION B
N
A. J. Carlson

FIG. 1

TABLE I

Class	Type	Number of Wells
	Idle one year or more	
1	Non-producers, outside producing area	1
2	Non-producers, within producing area	4
3	Producing some oil	44
4	Gas producers	..
	Idle less than one year	
5	Regular producers, lately on pump	4
6	Drilling wells	..
7	Water wells	..
8	Non-producers, within producing area	3

the cause of exceptional temperatures. In most wells, however, the results indicate conditions closely approximating thermal equilibrium.

The variation of temperature with depth is uniform, as shown by the absence of pronounced curvature in the normal depth-temperature curves. A notable characteristic of the curves is a convexity toward the temperature axis for shallow depths. This is in contrast to the pronounced opposite curvature observed in other California fields,[1] and may be attributed to low water content in the shallow sediments of the Coalinga area. Curves for the deeper wells low on the structure show slight reversals of curvature at a depth of approximately 1,500 feet, representing, perhaps, the transition from one general type of sediments to another. This can not be definitely correlated with the geologic strata from the available data.

ISOTHERMAL ELEVATIONS

Isothermal surface.—Elevations on a 100° F. isothermal surface are shown adjacent to the various wells in Figure 1. Values are omitted for a few of the wells because of insufficient data or very abnormal depth-temperature relations.

In the Westside field the elevations show a rise of the isothermal surface west and north, corresponding with the monoclinal structure. Such a rise, conforming with the structure, is evident also on the lower part of the Eastside anticline. However, on the upper part of the anticline the trend is seemingly downward.

The topography may be considered in accounting for such variations in the isothermal surface. In the entire productive area the ground

[1] Anders J. Carlson, "Geothermal Conditions in Oil Producing Areas of California," *Amer. Petrol. Inst. Prod. Bull. 205*, Pt. 5 (1930).

surface corresponds approximately with the geologic structure. The Westside part rises gently toward the west and north limits of the field which are along the base of the mountain slopes. The Eastside anticlinal nose is reflected in a fairly well defined ridge rising toward the northwest with increasing steepness. Local topographical features are fairly pronounced on this ridge. To this condition may be attributed some of the minor irregularities in the isothermal surface defined by the elevations in Figure 1.

Trend of isotherms.—The relation of structure and topography to the rock temperatures is most clearly shown on the vertical sections *A* and *B*. As indicated in Figure 1, these sections are taken through two series of wells situated respectively along the axis of the anticlinal nose and at right angles to this axis. In Figures 2 and 3 are represented the wells included in the sections and the trend of the isotherms at 10° intervals with respect to the ground surface and rock strata.

In general, the trend of the isotherms corresponds with the slope of the underground strata and ground surface, but it is to be noticed that the isotherms rise less rapidly as the crest of the structure and higher ground elevation are approached. In fact, at the highest points on the sections, the slope of the isotherms is opposite to that of the strata and

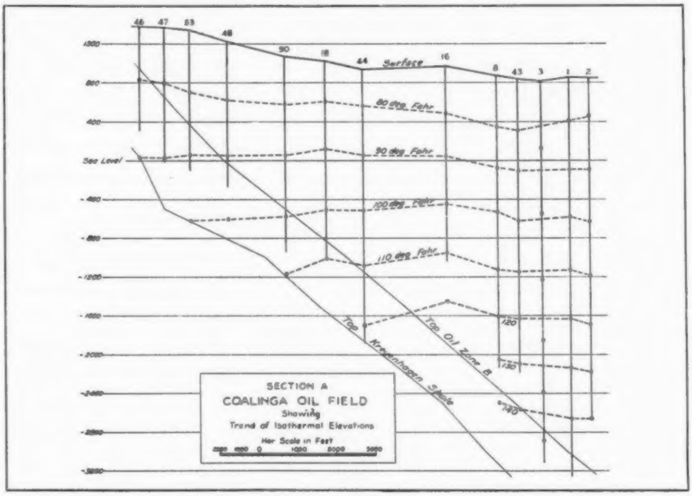


FIG. 2

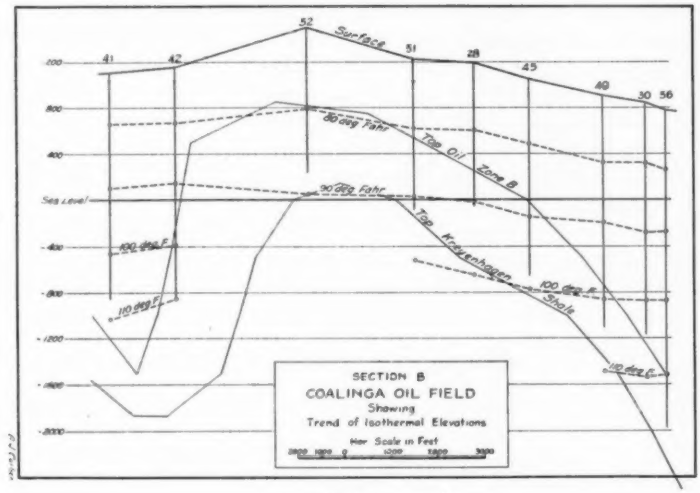


FIG. 3

ground surface. Too much significance can not be attached to this latter relation, as the wells in the upper part of the field are shallow and some of the points shown were extrapolated below the measured depths. However, there are several elevations of seeming validity which show a definite flattening of the isotherms. This is a normal condition below a topographic rise and indicates that the anticlinal structure does not cause the establishment of obviously abnormal rock temperatures.

On the lower part of the productive structure, as represented in Figure 2, the isotherms apparently dip more steeply than the ground surface, which gradually flattens toward the valley plain. Such a condition indicates that, as the level ground surface is approached and the effect of the topographical rise decreased, the trend of the isotherms is controlled by the dip of the strata and their increasing thickness toward the east. In this connection it should be noted that well 3 was obviously not in thermal equilibrium at the time of measurement; therefore, it was disregarded in representing the isotherms. The temperatures in wells 1 and 2 are also somewhat above normal because of a short period of idleness.

Another important feature shown in the sections is that the trend of the isotherms is seemingly not affected in passing from the non-pro-

ductive into the productive strata. This is significant with respect to the relation of oil accumulations and rock temperatures. Any physical or chemical phenomena associated with petroleum-bearing rocks and producing abnormal temperatures must be assumed to be relatively absent in this field. Otherwise these rich zones, with a thickness of several hundred feet, should have a noticeable effect on the isotherms.

SUMMARY

The foregoing results may be summarized as follows with respect to geothermal variations in the Coalinga area: (1) the relative variations of temperature with depth are controlled in the upper parts of the structure by surface topography and in the lower parts by the dip and increasing thickness of the strata; and (2) the presence of petroleum in the sediments does not affect appreciably the trend of rock temperatures.

Such relations are in essential agreement with those developed by the writer for the Los Angeles basin.[1] They suggest a general theory regarding geothermal variations in sedimentary areas. This may be stated as follows: the relative variation of temperature with depth in sedimentary areas is determined by the comparative elevation and configuration of the top and bottom surfaces of the sediments.

According to this theory, topography and thickness of sediments, representing respectively the positions of the top and bottom surfaces of the sediments in a specified area, are considered the controlling factors in maintaining certain normal geothermal conditions. The sedimentary strata may be conceived as forming a blanket through which heat is transmitted from the crystalline basement to the ground surface. The basement rocks, with relatively higher heat conductivity, represent to some extent the source of heat. Their temperature is related to depth, geologic age, and regional geological conditions. The mean temperature prevailing just below the ground surface depends in general on elevation and geographical location. Between these temperature limits are established the thermal gradients in the sedimentary strata.

Measurements in California oil fields have not revealed any marked deviations from normal temperature conditions which would conform with the foregoing theory. However, they can not be considered as conclusive evidence contrary to the association of high rock temperatures with oil-bearing structure. In certain regions physical and chemical phenomena peculiar to the oil accumulations may be the cause of ab-

[1]Anders J. Carlson, "Geothermal Variations in Oil Fields of Los Angeles Basin, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 8 (August, 1930).

normal temperatures. Also, some pronounced abnormalities might be expected on structures below a level ground surface, where topographical effects are eliminated or minimized. Whether such abnormalities can be attributed to the presence of a structure containing oil or to the relative thickness of the sedimentary beds merits further investigation.

GEOLOGICAL NOTES

ORISKANY GAS FIELDS OF PENNSYLVANIA AND NEW YORK

The gas pools of Tioga County, Pennsylvania, and Schuyler County, New York, discovered in 1930, constitute the most important development of recent years in the eastern fields. Tioga County is in north-central Pennsylvania, adjoining the New York state line. The Schuyler County area, which has been variously referred to as the Altay, Tyrone, or Dundee field, is about 35 miles north of the Tioga pool, between Seneca Lake and Keuka Lake. The producing sand in both fields is generally conceded to be the Oriskany sandstone of Lower Devonian age.

The six gas wells of the Tioga field have a total open-flow capacity of approximately 160,000,000 feet per day. Of this amount, the Meeker well is credited with 66,000,000 feet. Palmer No. 1, the discovery well, has been yielding about 2,500,000 feet per day through the winter. The other wells are shut in. The shut-in pressure of these wells is approximately the same, about 1,675 pounds. Their depths range from 3,775 to 4,197 feet, and surface elevations from 1,367 to 1,764 feet. The gas tests 1,030 B. T. U.

These six wells are located in the vicinity of the axis of the Sabinsville anticline, as mapped by Fuller.[1] Between them there is a range of sub-sea depth of the top of the sand amounting to 247 feet. The largest well is structurally the lowest, but was drilled deeper into the sand than the others. The productive area, to date, has a length of 7 miles and an extreme width of slightly more than 1 mile. There is a possibility that the sand may not be found productive throughout the entire 7 miles.

The axis of the Sabinsville anticline has been mapped for a distance of about 60 miles in Pennsylvania. At the northern border of the state the axis is nearly parallel with the state line, and the trend of the axis beyond the intersection is somewhat uncertain. The structural relief of the Sabinsville anticline in the Tioga Quadrangle amounts to more than 1,900 feet on the surface beds. Seven major anticlines in north-central Pennsylvania have been mapped.[2]

[1]Myron L. Fuller and W. C. Alden, "Gaines Quadrangle," *U. S. Geol. Survey Folio 92* (1903); Myron L. Fuller, "Elkland and Tioga Quadrangles," *Folio 93* (1903).

[2]Stanley H. Cathcart and Bradford Willard, "Gas in the Tioga Region, Pennsylvania," *Top. and Geol. Survey of Pennsylvania* (Harrisburg, 1931).

A dry hole has been completed about 1,000 feet from the discovery well, the Oriskany being encountered 397 feet lower in the former than in the latter. The Shoemaker well, which was dry in the Oriskany, had this sand 32 feet higher than the largest well in the field. They are nearly 5 miles apart, however, and the dry hole is somewhat up the regional dip from the producer. The Shoemaker had 54 feet of unbroken sand with a porosity of 11½ per cent, which compares favorably with the porosity of the sand in the producing wells. This sand contained neither gas, oil, nor water. The well is being deepened to the Medina.

There are seven Oriskany dry holes in Tioga County, widely separated, and thirty-four current operations. Two tests are being made farther east in Bradford County.

The surface beds of this area have been described in detail and mapped by Fuller.[1] There are no satisfactory key beds, and little or no detailed structure mapping has been done so far. Exposures affording reliable dip and strike readings are not plentiful.

There are twenty-seven gas wells in the Schuyler County, New York, field and eleven current operations in an area 6 miles in length and having an extreme width of 1.3 miles. The depths of these wells range from 1,700 to 2,200 feet. The average open-flow capacity is reported as 6,000,000-7,000,000 feet, but is probably not more than 6,000,000. The field has been defined on the southeast and partly on the north. The Oriskany outcrop is approximately 26 miles north at its nearest point. The most recent developments in this field have been in and near the village of Wayne, in the northwest corner of the county, where, unfortunately, a town-lot drilling campaign is under way. Very few of the wells in this area have any outlet as yet, but an 8-inch line extending through the field to Wayne is being laid.

The Oriskany outcrop follows an easterly course across New York from a point about 50 miles east of Buffalo to the vicinity of Albany, where it swings southward along the west side of the Hudson Valley, entering Pennsylvania at the easternmost point of Monroe County. It follows a devious course through the extremely folded regions of eastern and central Pennsylvania. It is missing in Lycoming County, which adjoins Tioga County on the south, but has been traced from a point a few miles southwest of Lycoming County into Maryland, with a gap of 20 miles in Center County. The great re-entrant formed by the

[1] *Op. cit.*

Oriskany outcrop marks a westward-plunging geosyncline, near the middle of which the Tioga field is located. The beds dip very abruptly from the Appalachian Mountains on the south into this broad trough.

The long anticlines, previously mentioned, approximately parallel the trend of the Appalachian folds. Along these axes in a large territory in both states there are possibilities of sufficient closure being developed locally, together with favorable sand conditions, to produce gas pools in the Oriskany and possibly in lower formations.

PARTIAL BIBLIOGRAPHY

(An asterisk (*) indicates the supply is exhausted)

**U. S. Geol. Survey Folios*: *No. 92* (Gaines, Pennsylvania); *No. 93* (Elkland-Tioga, Pennsylvania); *No. 169* (Watkins Glen-Catatonk, New York).

**Geological Hand Atlas of Pennsylvania, Second Geol. Survey of Pennsylvania* (Harrisburg, 1885).

**New York State Museum Bulletins: No. 101*, "Geology of the Penn Yan-Hammondsport Quadrangles" (D. D. Luther); *No. 81*, "Geology of the Watkins and Elmira Quadrangles" (John M. Clarke and D. D. Luther); *No. 128*, "Geology of the Geneva-Ovid Quadrangles" (D. Dana Luther).

Stanley H. Cathcart and Bradford Willard, *Gas in the Tioga Region, Pennsylvania, Top. and Geol. Survey* (Harrisburg, 1931).

Paul D. Torrey, "Geology of the Natural Gas Field of New York State," *Pennsylvania State College Min. Ind. Exp. Sta. Bull. 9* (State College, Pennsylvania, 1930).

*Frederick J. H. Merrill, *Geologic Map of New York, New York State Mus.* (1901). *U. S. Geol. Survey* topographic maps of all quadrangles in New York.

S. G. GARRETT

MANSFIELD, PENNSYLVANIA
May 8, 1931

AGE OF PRODUCING HORIZON AT KETTLEMAN HILLS, CALIFORNIA

The age of the oil horizon productive at Kettleman Hills at this writing has not been established beyond the fact that it represents some part of the Miocene. The age first assigned the horizon by geologists was Vaqueros (basal Miocene), this opinion being based on sandstones cropping out approximately 8 miles southwest of the field. As it was later discovered that these outcropping beds were not Vaqueros, but were Temblor (late lower or middle Miocene), the age classification of the Kettleman Hills oil sand was raised to agree with the new data. Occurrence in the oil horizon of a fossil determined as *Pecten andersoni*

Arnold, a form present in the Temblor formation, seemed to confirm the revised correlation. Some geologists have persisted, however, in maintaining that few wells thus far drilled at Kettleman Hills have gone deep enough to reach Temblor, but with a lack of definite evidence the term "Temblor sand" has come into general use.

Paleontological and mineralogical work by the writer indicates that little, if any, of the oil horizon so far penetrated at Kettleman Hills is as old as the Temblor, but that most of it is correlated with sandy facies in the lower part of the overlying Monterey.

This indication was first obtained from a study of the North Belridge section. Deep wells drilled in the North Belridge field have encountered light gray, fine, somewhat friable arkosic sandstone. A horizon in this sandstone about 150 feet below its top contains shells identified as *Pecten andersoni* Arnold, on which basis the age of the sandstone has commonly been held to be Temblor. The results of a micropaleontological study of brown shales penetrated at North Belridge both above and below the sandstone containing the form mentioned are definitely in disagreement with such a view. The foraminiferal assemblage in shale about 430 feet above the fossil horizon, and also in a thin layer about 200 feet below it, is typical of the *Valvulinaria californica* zone. This zone is well known to California micropaleontologists. Its stratigraphical position in the California Miocene is established as overlying the highest horizon of the Temblor. The form from the wells which has been classified as *Pecten andersoni* therefore ranges above the Temblor.

In the type section[1] of the Temblor at Carneros Creek the *Valvulinaria californica* zone is stratigraphically above the sandstone defined by Anderson as the top of the formation.

In the type Monterey section as redefined by Hanna,[2] the *Valvulinaria californica* zone characterizes the basal beds which rest unconformably on Santa Lucia quartz diorite.

These correlations indicate that the horizon of *Pecten andersoni* penetrated in wells at North Belridge is equivalent to Monterey, not Temblor.

In the opinion of the writer, the first prominent sandstone at Kettleman Hills and Lost Hills encountered in wells below the brown shale is

[1]F. M. Anderson and Bruce Martin, "Neocene Record in the Temblor Basin, California," *Proc. California Acad. Sci.*, 4th Ser., Vol. 4, No. 3 (1914), p. 39.

[2]G. D. Hanna, "The Monterey Shale of California at its Type Locality with a Summary of its Fauna and Flora," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 10 (October, 1928), pp. 969-83.

TABLE I

	Type Temblor (After May and Gilboe)	Type Monterey	North Belridge	Feet	Lost Hills	Feet	Kettleman Hills	Feet
MONTEREY			Brown shale. Arenaceous *Foraminifera* and collophane oölites or so-called "sporbo"	170	Brown shale. Arenaceous *Foraminifera*. A few fish remains		Brown shale. Arenaceous *Foraminifera*. A few fish remains	
			Brown shale. Calcareous foraminiferal assemblage typical of *Valvulineria californica* zone	60				
			Brown shale grading to sandy shale. Barren of calcareous *Foraminifera*. Rich in "sporbo"	220	Brown shale grading to sandy shale. Rich in "sporbo"	300	Brown shale grading to sandy shale. Rich in "sporbo"	155
							—Top of oil zone—	
			Light gray, fine, arkosic sandstone. A small proportion of white clay matrix	150	Light gray, fine, arkosic sandstone. A small proportion of white clay matrix	140	Light gray, fine, arkosic sandstone. A small proportion of white clay matrix. Alternates with irregularly distributed streaks of brown shale identical with that above. *Pecten andersoni* commonly occurs near the top. The maximum thickness of this part of the oil zone is	700
			Same, containing *Pecten andersoni*	10				
			Same, no fossils	200				
	Valvulineria californica zone	*Valvulineria californica* zone	Brown shale identical with that above. Contains "sporbo" throughout. *Valvulineria californica* assemblage at top	300	(Unexamined)			
TEMBLOR	"Button bed" sandstone Shale, some sandstone Carneros sandstone	(Absent)	Gray, medium-grained, hard calcareous sandstone. Small black pebbles. Fragments of pelecypods and gastropods. A poor micro-fauna in shaly streaks suggests an age not older than upper Temblor		(Unexamined)		Gray, medium-grained, hard calcareous sandstone. Small black pebbles. Fragments of pelecypods and of a *Turritella*. A poor micro-fauna in shaly streaks suggests an age not older than upper Temblor	

also Monterey in age. The *Valvulinaria californica* micro-fauna has not been found by the writer in samples obtained from wells in these fields (possibly because none of the studied wells was cored continuously). However, petrographic similarity of the sandstone in all three fields, the finding of no mega-fossils except *Pecten andersoni*, and peculiarities of the brown shale just above the sandstone, indicate that the correlation of the North Belridge, Lost Hills, and Kettleman Hills sections is that shown in Table I.

CONCLUSIONS

The upper 700 feet of the known oil horizon at Kettleman Hills represents a sandy facies of the *Valvulinaria californica* zone. All of this zone is established as being stratigraphically higher than the type Temblor, and represents the lower part of the type Monterey. The age of the basal several hundred feet of the oil horizon is at present indeterminate, but seems to be not older than upper Temblor.

Fossils from wells at North Belridge and Kettleman Hills determined as *Pecten andersoni* Arnold indicate that this form is not confined to the Temblor, but ranges higher.

PAUL P. GOUDKOFF

LOS ANGELES, CALIFORNIA
May 19, 1931

CLASTIC DIKE IN FORT HAYS CHALK, KANSAS

In north-central Kansas the Fort Hays chalk, lower member of the Niobrara formation of Cretaceous age, rests conformably on the Carlile shale. The Fort Hays here has an average thickness of approximately 50 feet and consists of white and buff beds of chalk separated by thin beds of yellow or gray shale. Directly underlying this chalk and at the top of the Carlile is the Codell sandstone which has a thickness ranging from 18 to 30 feet near its type locality at Codell, Rooks County, Kansas. The sand itself is rather fine-grained and of a powder-blue color. It becomes shalier toward the south and west and changes entirely to blue-black fissile shale.

In T. 10 S., R. 16 W., approximately 3 miles east of Codell, there is an excellent exposure of a clastic dike of this Codell sandstone extending almost vertically up into the Fort Hays. The width of the dike is approximately 8 inches and it extends at least 18 feet upward. The material in the dike is identical with the sandstone beneath.

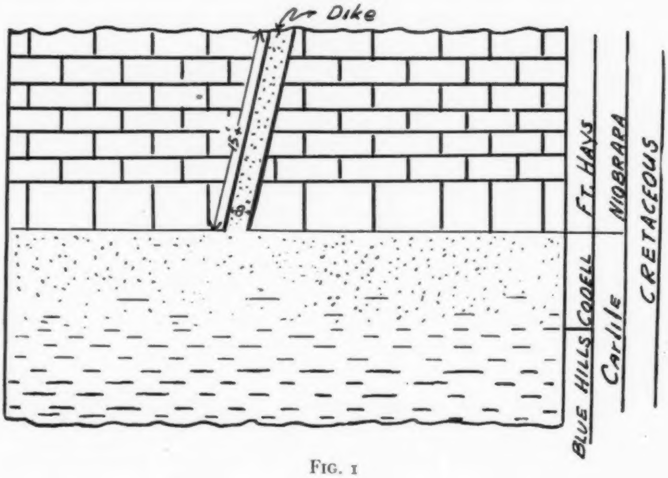


FIG. 1

The dike was undoubtedly formed when at one time a crack occurred in the chalk either from settling or other forces and ground waters rushed in from beneath through the opening, carrying the sand and filling the crevice.

J. M. MCMILLAN, JR.

PENN-YORK NATURAL GAS CORPORATION
ELMIRA, NEW YORK
May 25, 1931

EAST TEXAS OIL FIELD

The East Texas oil field is in Rusk, Smith, Gregg, and Upshur counties in northeastern Texas. On October 11, 1930, the E. M. Joiner Bradford No. 3, the discovery well of the field, was completed, flowing 226 barrels in 24 hours, in the Woodbine sand at a depth of 3,584-3,592 feet. On December 30, 1930, Bateman *et al.* Crim No. 1, located in Rusk County near Kilgore, encountered the Woodbine sand at 3,640-3,652 feet and showed an initial production of 597 barrels in 55 minutes. On January 30, 1931, J. B. Farrell *et al.* Lathrop No. 1, located in Gregg County west of Longview, was completed in the Woodbine sand at 3,568-3,587 feet, flowing 362 barrels in 30 minutes. Subsequent development has proved that these three widely separated producing areas are

all a part of one great field that has a length of approximately 36 miles and a width ranging from 4 to 7 miles.

The surface formations in the East Texas field are Tertiary in age. The following is the stratigraphic section encountered in wells.

Tertiary	Mount Selman	Queen City Reklaw
	Carrizo	
	Wilcox	
	Midway	
Upper Cretaceous	Navarro	
	Taylor	Upper Taylor Pecan Gap (Annona) Brownstown
	Austin (Tokio)	
	Woodbine	

Figure 2 shows the marked westward thickening of the Upper Cretaceous strata lying below the Pecan Gap chalk.

Accumulation of oil in the East Texas field is the result of the updip thinning or wedging-out of the Woodbine sand on the west flank of the Sabine uplift. Regional synclines afford closure on the north and south ends of the field. Figure 1 shows the eastern limit of the Woodbine sand body as well as the relationship to the Sabine uplift.

The eastern limit of the Woodbine sand body has been regarded in the past as a buried shore line. Recent developments, however, indicate that it may be an erosional, rather than a depositional, feature. In other words, the true Woodbine shore line was originally some distance east of the present eastern limit of the Woodbine. Upward movement of the Sabine uplift during Eagle Ford deposition caused the sea to recede many miles westward with a period of non-deposition and erosion on the west flank of the Sabine uplift. At the beginning of Austin deposition, general subsidence of the entire Sabine land mass occurred with the consequent deposition of Austin sediments in direct contact with the Woodbine. The producing sand of the field, therefore, is the basal part of the Woodbine.

The producing sand ranges in thickness from a few feet in the eastern part of the field to as much as 100 feet near the western edge. The Woodbine formation thickens within a short distance westward into the East Texas Salt-Dome basin. The top of the producing sand in the extreme eastern part of the field is encountered at approximately 3,150 feet below sea-level and the salt-water level on the western edge of the

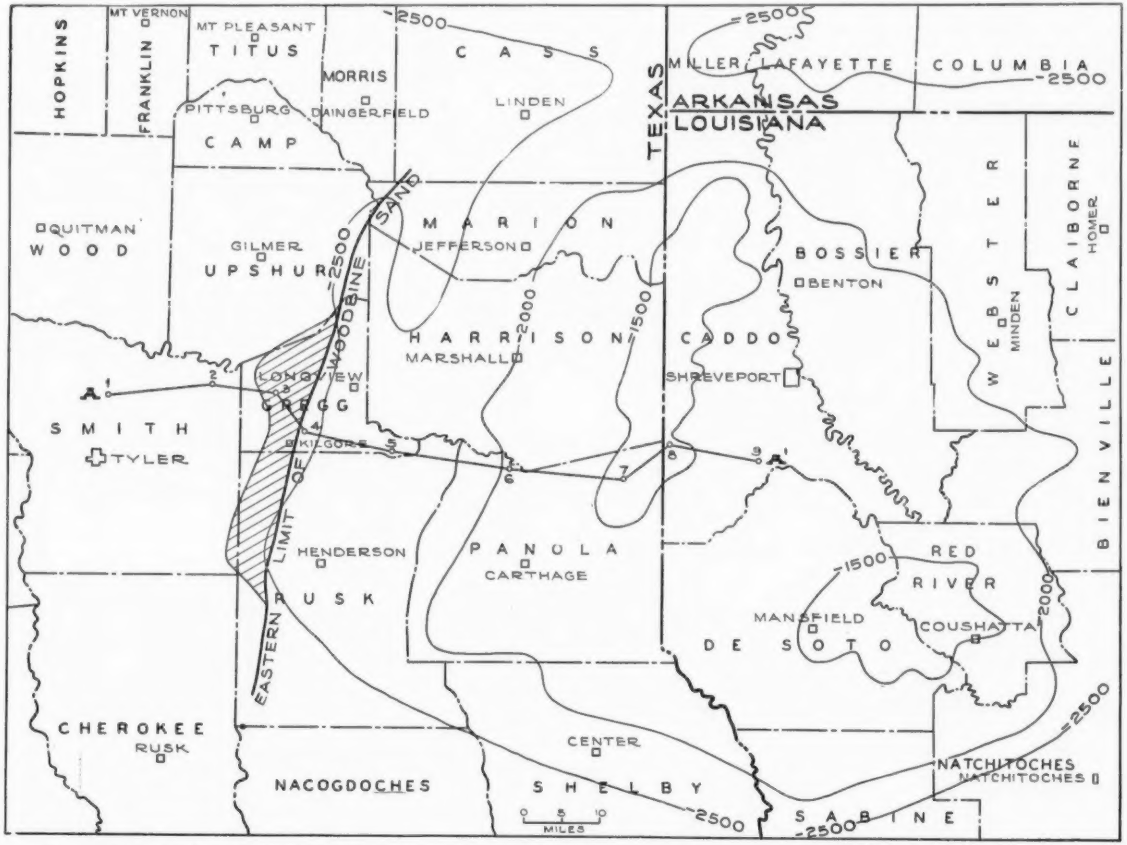


FIG. 1.—Map showing relationship of East Texas field to Sabine uplift, contoured on base of Pecan Gap chalk. Datum, mean sea-level. Shaded area indicates productive region in East Texas field. *A-A'*, cross section shown in Figure 2.

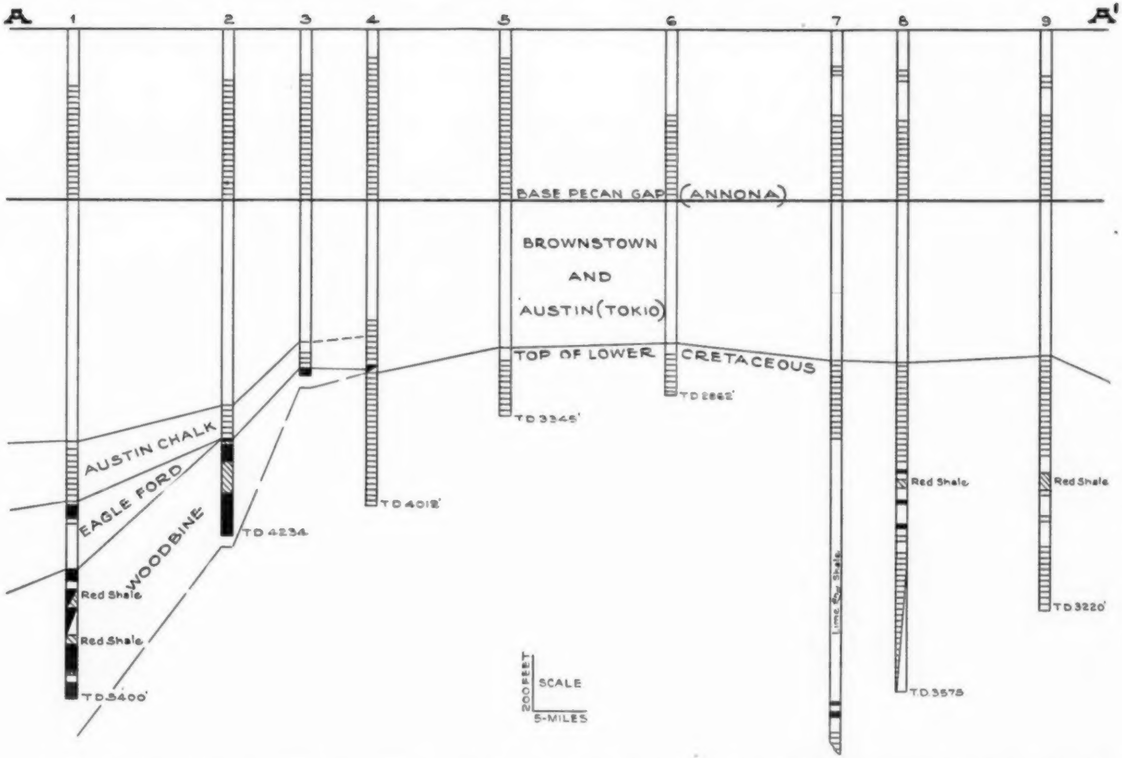


FIG. 2.—West-east cross section from East Texas Salt-Dome basin to Sabine uplift showing varying thickness of formations of lower part of Upper Cretaceous, referred to base of Pecan Gap chalk. 1. Amerada Petroleum Corporation's Christian No. 1, Smith County. 2. Owen Sloan's Starnes No. 1, Smith County. 3. Sinclair Oil and Gas Company's Cole No. 1, Gregg County. 4. D. H. Byrd's Elder No. 1, Gregg County. 5. Sabine Petroleum Company's Simmons No. 1, Gregg County. 6. Panola Petroleum Company's Flanagan No. 1, Panola County. 7. Natural Gas Prod. Company's Moore No. 1, Panola County. 8. Arkansas Fuel Company's Brumble No. 1, Sec. 18, T. 16 N., R. 16 W., Caddo Parish, Louisiana. 9. Mayfair Oil Company's Hendricks No. 1, Sec. 29, T. 16 N., R. 14 W., Caddo Parish, Louisiana.

field is encountered at approximately 3,317 feet below sea-level. The oil is of paraffine base and has an average gravity of 39° A. P. I.

The development of the East Texas field presents many difficult problems. Although the limits of production have not been definitely established in all directions, sufficient outpost wells have been drilled to indicate a productive area of approximately 100,000 acres. Many of the leases are small tracts which, if developed in the ordinary manner, will require the drilling of very many unnecessary wells. The high permeability of the Woodbine sand makes possible the ultimate recovery of oil from a large number of acres per well. In the present status of the oil industry, only a program of coöperation of the lease owners involving the proper spacing of wells to drain the maximum number of acres per well with the consequent elimination of all unnecessary locations, can result in profitable operation.

P. W. McFarland

Dallas, Texas
June 10, 1931

REVIEWS AND NEW PUBLICATIONS

Das Erdöl (Petroleum). By C. ENGLER and H. HÖFER. 5 vols. 2d ed., completely revised. Vol. 2, Pt. 2, *Spezielle Geologie des Erdöls in Europa, ausschliesslich Russland* (Geology of Oil Occurrences in Europe exclusive of Russia). Edited by J. Tausz. Published by S. Hirzel, Leipzig (1930). xvi + 438 pp., 121 figs., 25 pls. Paper, RM. 62; cloth bound, RM. 65.

This volume of the new edition of Engler and Höfer's famous text-book furnishes much more information regarding the geology of the European oil occurrences than Volume 2 of the first edition, which treated the entire world.

The material on the important oil-producing countries of Europe has been prepared by well known geologists who have specialized in these areas and the articles are not merely a tabulation of oil occurrences with brief mention of geological formations, as was generally the case in the earlier volume, but they give a general geological and structural summary of the country and the oil-bearing regions illustrated with geological maps and cross sections.

The most important chapters are on Roumania and Poland, by Macovei and Friedl, respectively. They occupy the first 130 pages, following the general introduction by Moos.

Much shorter chapters by other writers on Czechoslovakia, Hungary, Bulgaria, European Turkey, Albania and Greece, Jugoslavia and Austria follow, and constitute an excellent reference for oil occurrences in these countries as well as a source for geological information.

The chapter on Germany by J. Stoller is especially good in its description of the oil-producing areas in Germany. Chapters on France, Alsace, Switzerland, Italy, Spain and Portugal, Netherlands, Belgium, Great Britain, Norway, Sweden, and the Baltic states are in general brief and give little geological information, because of the slight importance of these countries in regard to oil occurrence. There are 425 pages of text and a good index of localities occupying 29 pages. Bibliographic references are numerous throughout the text.

The volume is recommended as a very useful reference work to those wishing to inform themselves upon European oil fields and oil-field geology, and the general discussion of European geology and structural features in the introduction will greatly assist any geologists who visit Europe for the first time.

W. P. HAYNES

PARIS, FRANCE
May 21, 1931

The Geology of Petroleum, 2d ed. By WILLIAM HARVEY EMMONS. McGraw-Hill Book Company, New York (1931). 736 pp., 435 figs. Price, $6.00.

The second edition of Emmons' *Geology of Petroleum* "is intended to serve primarily as a text-book and secondarily as a brief compendium or manual relating to the geology and deposits of oil-bearing areas." The author briefly discusses many subjects and fields, including even the minor ones—all of which makes the book a valuable reference, but does not contribute in an equal degree to its value as a text, as the brief treatment necessitates inadequate development of some of the basic ideas.

The revision has been very thorough and the book brought up to date. Half the illustrations of the first edition were discarded, but more illustrations have been added than were contained in the original edition. Some of the new ideas included are the recent studies of source materials, objections to the carbon-ratio theory, discussions of buried hills and arches, importance of the development of porosity at unconformities in limestone reservoirs, and recent ideas on origin of petroleum. When one realizes the length of time and labor required merely for the publication of a book after the manuscript is complete, it is pleasing to note that such recent fields as Oklahoma City, Oklahoma; Van, Texas; Hobbs, New Mexico; Kettleman Hills, California; and Las Palmas, Venezuela, are described. Material as recent as October, 1930, is included.

The principles of petroleum geology are first briefly discussed. Behavior of wells, rock pressures, maps, and logs are important topics, but they do not seem to be sufficiently related to the central theme of the book to justify the amount of space devoted to them, especially as space is at a premium. Fissures and porosity are discussed as if belonging to the same category of structural features as synclines and anticlines, which is not conducive to clear thinking. The size of capillary and sub-capillary openings is given to three significant figures, an error that is found in practically all the literature. O. E. Meinzer[1] has previously noted this error, but it will probably die a harder death than the proverbial cat. It is significant to notice that estimates of total future reserves of the United States, given in the first edition, are here omitted.

The larger part of the book discusses the geology of the petroliferous areas. The orderly arrangement of the individual pools within the fields and larger areas permits general description of the regional geology, and consequently only the local characteristics are discussed with respect to the pools. As a result, the essential characteristics of the individual pools are summarized, although only a few lines or pages are devoted to each of them. One-third of such discussions is devoted to the Mid-Continent area, which is not surprising when its size, production, and diversity of conditions, as well as the available literature, are considered.

The trend of development during the past 10 years can be observed by comparing the two editions. Because of the developments in Arkansas, Lou-

[1] O. E. Meinzer, "Outline of Ground Water Hydrology," *U. S. Geol. Survey Water Supply Paper 494* (1923), pp. 18-19. Also cited by Robert Wesley Brown, in *Valuations of Oil and Gas Lands* (1924), p. 75.

isiana, New Mexico, and Texas, especially in the Panhandle and western part, four times as much space has been devoted to the Mid-Continent area of these states. The developments of new areas and of the Ordovician production are responsible for a material increase in the space devoted to the remainder of the Mid-Continent area. The section on eastern United States has undergone the least revision, although recent studies, including those due to flooding at Bradford, have been cited. The chief interest in South America has been transferred from Peru and Colombia to Venezuela, and more attention has been devoted to western Canada and western Europe. The space devoted to the Gulf Coastal area, Russia, Asia, Africa, and Oceanica has been doubled, probably because of an increase in available literature. To provide for the additional material some examples and production data were eliminated and descriptions of fields important 10 years ago, but less so now, materially reduced. Nevertheless, the size of the book has been increased.

The publications of The American Association of Petroleum Geologists are an important source of material even in foreign fields. They constitute one of the leading sources for new information with respect to the Mid-Continent area and are almost the only source for such information with respect to the Gulf Coastal salt domes.

A book such as Emmons' *Geology of Petroleum* must necessarily be chiefly a compilation of data, and as such it is a most useful reference book, not only because of the text and figures, but also because of many footnote references to original sources. In comparing the first and second editions, one is immediately impressed by the tremendous amount of work done in the better organization of the old material and in bringing the subject up to date.

ROBERT WESLEY BROWN

TULSA, OKLAHOMA
June 15, 1931

RECENT PUBLICATIONS

ALBANIA

"Sur la stratigraphie et la faune nummulitique du Flysch de l'Albanie," (Stratigraphy and Nummulitic Fauna of the Flysch of Albania), by Mme. Henry de Cizancourt. *Bull. de la société géologique de France*, 4^e serie, t. 30 (1930), pp. 195-211. 1 fig., 2 pls.

ASIA

The Natural History of Asia, Vol. IV (1931), "The Permian of Mongolia," by A. W. Grabau (Univ. of Peking). The second to be published of 12 quarto volumes of the final reports of the Central Asiatic Expedition (Amer. Mus. Natural History, 77th Street and Central Park West, New York). The other published volume is Vol. II (1927), "The Geology of Mongolia," by C. P. Berkey and F. K. Morris. Vol. IV: 4 pts., 20 chaps., 72 text figs., 35 pls., xliii + 665 pp., colored geologic map. 8½ × 2⅛ inches. Cloth. Price, $10.00.

CHINA

"The Geological Structure of Tseliutsin, Szechuan, the World's Oldest Bore Field," by Arnold Heim. *Geol. Survey of Kwangtung and Kwangsi Spec. Pub. 6* (Canton, China, 1930). 28 pp., 9 pls.

EUROPE

"Bergmännischer Abbau von Erdöllagern" (Mining Abandoned Petroleum Deposits), by Waclaw Holewinski. "Pechelbronn," *Intern. Zeit. f. Bohrtech., Erdölb. und Geol.* (Vienna, May 1, 1931), pp. 65-69, 2 figs. "Wietze" (June 1, 1931), pp. 81-85, 3 figs. Extracts from *Naphtha*, Heft 11-12 (November-December, 1930).

"Die Alpen als Doppelorogen" (The Alps as Double Orogeny), by E. Kraus. *Geol. Rundschau* (Berlin), Bd. 22, Heft 2 (May 30, 1931), pp. 5-78, 1 fig.

GENERAL

"Die Untersuchungsergebnisse an Gesteinsdeformationen (Petrotektonik)" (Results of Investigations of Rock Deformation—Petrotectonics), by Ludwig Rüger. *Geol. Rundschau*, Bd. 22, Heft 2, pp. 79-125, 10 figs.

The Engineering Index, 1930 (Amer. Soc. Mech. Eng., 29 West 39th Street, New York). Encyclopedic bibliography of engineering literature of the world for 1930. 50,000 reference items; 5,000 subject headings; author index. 2 vols. Price postpaid, $50.00.

Geology of Petroleum, by William Harvey Emmons. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York, New York, 1931.) 2d ed. (revised). 736 pp., 435 figs.

Grundprobleme der Geologie, eine Einführung in geologisches Denken (Principles of Geology, an Introduction to Geology), by Serge von Bubnoff. (Gebrüder Borntraeger, Berlin, 1931.) viii + 238 pp., 48 figs. Bound, 11 RM., 60 Pfg.

Oil and Petroleum Year Book (May, 1931). International reference work on oil companies and allied companies, containing lists of officials and data on organization and operation. Published by Walter E. Skinner, 15 Dowgate Hill, Cannon Street, London, E. C. 4. lx + 340 pp. 5½ × 8¼ inches. Cloth. Price, net post free, 8s. 6d.

Petroleum Development and Technology, 1931. Trans. Amer. Inst. Min. Met. Eng. Petrol. Div. (29 West 39th Street, New York.) 657 pp. Price, net, $5.00.

Petroleum Engineering Handbook, edited by Rex W. Wadman. 2d ed. (1931). Published by publishers of *World Petroleum* (New York) and *Petroleum World* (Los Angeles). Forty authorities contribute articles on drilling, producing, transportation, refining, management, appraisal, et cetera. Address Bendix Building, Los Angeles, California. 500 pp., illus. 9 × 12 inches. Price, $5.00.

GEOPHYSICS

"Progrès de la géophysique appliquée," (Progress in Applied Geophysics) by J. B. Ostermeier-Althegnenberg. *La Revue Pétrolifère* (Paris, May 23, 1931), pp. 655-59; 8 figs.

GERMANY

Report on the Oil Fields of Northwest Germany, by Ira Rinehart. (Lord Baltimore Press, Baltimore, Maryland, 1930.) 87 pp., illus.

"Das Erdöl in Deutschland" (Petroleum in Germany). Special number of *Petroleum Zeitschrift* (Berlin), Vol. 27, No. 21 (May 20, 1931). Among other articles, contains "Über Geophysikalische Untersuchungen im Salzdom-Gebiet westlich Celle und im Küstengebiet von Texas und Louisiana," by Carl Schmidt, and "Erdöl in Deutschland," by F. Rainer.

"Gedanken über tektonische Erscheinungsformen im Wiener Becken" (Tectonics of the Wiener Basin), by Friedrich Musil. *Internationale Zeits. f. Bohrtechnik, Erdölbergbau und Geologie* (Vienna), No. 10 (May 15, 1931), pp. 76-78, 7 figs.

ILLINOIS

List of Publications on the Geology of Illinois (Illinois Geol. Survey, Urbana, May 1, 1931). 76 pp.

KENTUCKY

Oil and Gas in the Bluegrass Region of Kentucky, by W. R. Jillson. *Kentucky Geol. Survey* (Frankfort), Ser. 6, Vol. 40 (1931). 123 pp., 45 photographs, maps, and diagrams. Cloth, 6 × 9 inches.

LOUISIANA

Tentative Correlation of the Named Geologic Units of Louisiana, compiled by M. Grace Wilmarth, secretary of Committee on Geologic Names (U. S Geol. Survey, Washington, D. C., March, 1931). Chart, 29 × 19 inches.

NEBRASKA

"Deep Wells of Nebraska," by G. E. Condra, E. F. Schramm, and O. L. Lugn. *Nebraska Geol. Survey Bull. 4*, 2d Ser. (1931). 288 pp., 7 figs.

OKLAHOMA

"An Engineering Study of the Seminole Area, Seminole and Pottawatomie Counties, Oklahoma," by R. R. Brandenthaler, W. S. Morris, and C. R. Bopp. *U. S. Bur. Mines Rept. of Investigations 2997* (1931). 2d edition. In coöperation with State of Oklahoma. 181 mimeographed pp., 38 illus., 38 tables. (U. S. Bur. Mines, Washington, D. C., or Bartlesville, Oklahoma.) Free.

Tentative Correlation of the Named Geologic Units of Oklahoma, compiled by Grace Wilmarth, secretary of Committee on Geologic Names (U. S. Geol. Survey, Washington, D. C., January, 1931). 3 charts, one 18 × 29, and two 24 × 27 inches.

SALT DOMES

The following papers appear in the May, 1931, issue of *The Journal of the Institution of Petroleum Technologists* (London).

"Salt Domes of Texas and Louisiana Gulf Coast," by Frederick G. Clapp, pp. 281-99, 1 fig.

"Salt Domes of North Germany," by James Romanes, pp. 252-59.

"Some Depositional and Deformational Problems," by G. M. Lees, pp. 259-80, 6 figs.

"Salt Domes in Persia," by J. V. Harrison, pp. 300-20, 9 figs.

"Intrusive Salt Bodies in Coastal Asir, South Western Arabia," by Arthur Wade, pp. 321-30, 2 illus.

UTAH

"Geologic Structure of Parts of Grand and San Juan Counties, Utah," by A. A. Baker, C. H. Dane, and E. T. McKnight. Map in advance of publication of full report. Copies may be obtained from U. S. Geol. Survey, Washington, D. C.; R. R. Wooley, 313 Federal Building, Salt Lake City, Utah; or Robert Follansbee, 403 Post Office Building, Denver, Colorado.

"Geologic Structure of the Monument Valley-Navajo Mountain Region, Utah," by A. A. Baker. Preliminary edition of map in advance of publication of report. Copies may be obtained from addresses shown in preceding paragraph.

WYOMING

"Value of Ceramic Tests in Subsurface Correlation of Cretaceous Shales in Central Wyoming," by C. E. Dobbin and E. A. Swedenborg. *Amer. Inst. Min. Met. Eng. Tech. Pub. 424* (June, 1931). (Preprint of paper for February, 1932, meeting, New York City.) 12 pp., 3 figs.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Lowell Alfred Adams, Los Angeles, Calif.
Ira H. Cram, Arthur E. Remington, A. A. Langworthy
Ralph Leroy Belknap, Ann Arbor, Mich.
William A. Thomas, R. B. Newcombe, R. A. Smith
Kenneth Leonard Gow, Los Angeles, Calif.
Desaix B. Myers, H. W. Hoots, Irvine E. Stewart
John Clarence Karcher, Dallas, Tex.
Geo. Edwin Dorsey, F. B. Plummer, F. W. De Wolf
Clarence Leonard Lee, Wahoo, Neb.
R. J. Riggs, C. W. Roop, E. F. Schramm
Alvin Leonard Lugn, Lincoln, Neb.
E. F. Schramm, Raymond C. Moore, A. C. Trowbridge
William Claude McGlothlin, Tyler, Tex.
A. R. Denison, H. E. Minor, D. J. Edson
Ludger Mintrop, Hannover, Germany
Donald C. Barton, A. T. Schwennesen, J. Brian Eby
Ira A. Williams, Portland, Ore.
John P. Buwalda, George D. Louderback, Clarence B. Osborne
Joseph G. Wilson, San Antonio, Tex.
Earle R. Wall, K. H. Crandall, T. J. Galbraith
Walter S. Yarwood, Calgary, Alta., Canada
H. M. Hunter, S. E. Slipper, Theodore A. Link
Charles C. Zimmerman, Houston, Tex.
R. S. Powell, Paul Weaver, Louis A. Scholl, Jr.

FOR ASSOCIATE MEMBERSHIP

Stockton Donley Broughton, San Antonio, Tex.
Henry J. Hawley, T. J. Galbraith, Earle R. Wall
Arthur B. Brown, Los Angeles, Calif.
William S. W. Kew, Herschel L. Driver, Graham B. Moody
Otto E. Brown, Chickasha, Okla.
Clyde M. Becker, Roger W. Sawyer, O. E. Nordman

Charles Howard Dresbach, Amarillo, Tex.
A. N. Mackenzie, William B. Heroy, R. E. Somers
James Edward Lytle, Monroe, La.
R. A. Steinmayer, Preston Fergus, John S. Ivy

FOR TRANSFER TO ACTIVE MEMBERSHIP

Wilbur Eugene Bakke, Port Allegany, Pa.
W. C. Bean, Sherwood Buckstaff, R. D. Jones
William F. Barbat, Taft, Calif.
S. H. Gester, Thomas W. Koch, Ernest K. Parks
Carl Fred Barnhart, Wichita, Kan.
W. E. Bernard, Roy H. Hall, W. B. Wilson
Lawrence D. Bartell, Guthrie, Okla.
Harry E. Crum, T. F. Newman, R. B. Rutledge
Charles Lothrop Bartlett, Beaumont, Tex.
P. S. Justice, R. W. Pack, James A. Waters
Max Bornhauser, Dallas, Tex.
Sam M. Aronson, Walter A. English, Wallace Gordon
Howard S. Bryant, Wichita, Kan.
L. W. Kesler, F. J. Miller, Clare J. Stafford
Frank B. Carter, Hollywood, Calif.
E. F. Davis, Art R. May, Roy R. Morse
William Donald Chawner, Philadelphia, Pa.
J. E. Brantly, Roy E. Dickerson, R. H. Palmer
William Hurst Curry, Jr., San Antonio, Tex.
F. W. Bartlett, Baker Hoskins, A. W. Weeks
Phillip L. Dana, Tulsa, Okla.
W. E. Bernard, Roy H. Hall, W. B. Wilson
Wendell Baum Gealy, Pittsburgh, Pa.
Roswell H. Johnson, J. G. Montgomery, Jr., R. E. Somers
Guy Balcer Gierhart, Laredo, Tex.
L. P. Teas, W. A. Baker, Jr., Olin G. Bell
Ralph E. Grimm, Iowa City, Iowa
E. N. Lowe, W. C. Morse, A. C. Trowbridge
Delmar R. Guinn, Roswell, N. Mex.
L. R. Hagy, J. M. Nisbet, F. S. Prout
E. F. Hagan, Morgantown, W. Va.
John W. Emch, Ray V. Hennen, David B. Reger
Victor G. Hill, Tulsa, Okla.
E. F. Bullard, L. G. Mosburg, A. L. Solliday
J. Wilkinson Hoover, Midland, Tex.
Herman F. Davies, T. J. Galbraith, Graham B. Moody
Marion King Hubbert, New York, N. Y.
H. N. Coryell, J. J. Galloway, G. Marshall Kay
David Glynn Jones, Masjia-i-Suleiman, Persian Gulf
F. E. Wellings, E. W. Shaw, B. K. N. Wyllie
Ralph Charles Lamb, Amarillo, Tex.
Victor Cotner, L. R. Hagy, A. P. Loskamp

Bill Wilkinson Lincoln, Oklahoma City, Okla.
V. E. Monnett, A. H. Richards, Roger W. Sawyer
Oscar M. Longnecker, Jr., Houston, Tex.
J. M. Vetter, Melbert E. Schwarz, Charles Laurence Baker
Vaughn C. Maley, McCamey, Tex.
J. Ben Carsey, Cecil L. Chatman, L. P. Teas
John Thomas McGlothlin, Meridian, Miss.
B. W. Blanpied, Corbin D. Fletcher, Roy T. Hazzard
Joseph M. McMillan, Jr., Elmira, N. Y.
John S. Barwick, John R. Reeves, C. R. Thomas
Clark D. Millison, Tulsa, Okla.
Fanny C. Edson, Frank C. Greene, R. E. Shutt
Walter L. Moreman, Fort Worth, Tex.
R. C. Moore, Gayle Scott, W. M. Winton
William B. Mullins, Shawnee, Okla.
C. N. Housh, W. A. Maley, H. E. Minor
Virgil Pettigrew, Wichita Falls, Tex.
Vernon E. Autry, C. W. Clark, M. M. Garrett
John S. Redfield, Norman, Okla.
Charles N. Gould, V. E. Monnett, C. E. Decker
Cecil Dodson Robinson, Fort Smith, Ark.
George C. Branner, Marion H. Funk, Albert W. Giles
Charles Morrison Ross, Tulsa, Okla.
E. F. Bullard, L. G. Mosburg, A. L. Solliday
Fred E. Roth, Jr., Russell, Kan.
R. Clare Coffin, Thomas H. Allen, G. G. Frazier
Henry F. Schweer, Norman, Okla.
Sherwood Buckstaff, Robert M. Whiteside, W. C. Bean
Jefferson A. Stone, Tulsa, Okla.
V. E. Monnett, T. E. Weirich, Charles N. Gould
Clyde G. Strachan, Pittsburgh, Pa.
K. C. Heald, James R. Pyle, R. E. Somers
Girard Emory Wheeler, Brooklyn, N. Y.
J. J. Galloway, H. N. Coryell, G. Marshall Kay
Glen Clark Woolley, Wichita, Kan.
George R. Chatburn, Jr., R. Clare Coffin, E. C. Moncrief

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

Lovic P. Garrett, *chairman*, Gulf Production Company, Houston, Texas
Frank Rinker Clark, *secretary*, Mid-Kansas Oil and Gas Company, Tulsa, Oklahoma
Sidney Powers, Box 2022, Tulsa, Oklahoma
L. Courtney Decius, Associated Oil Company, San Francisco, California
F. H. Lahee, Box 2880, Dallas, Texas

GENERAL BUSINESS COMMITTEE

R. S. McFarland (1932), *chairman*, 735 Philcade Building, Tulsa, Oklahoma
David Donoghue (1932), *vice-chairman*, 1116 Fort Worth Natl. Bank Building, Fort Worth, Texas

C. A. Baird (1933)
S. P. Borden (1932)
J. P. Bowen (1932)
R. Clare Coffin (1933)
Victor Cotner (1932)
L. Courtney Decius (1932)
R. K. DeFord (1933)
H. B. Fuqua (1933)
Lovic P. Garrett (1933)
S. A. Grogan (1933)
W. R. Hamilton (1933)
Harry R. Johnson (1933)
L. W. Kesler (1933)
R. S. Knappen (1933)
Frederic H. Lahee (1932)
C. R. McCollom (1932)
H. D. Miser (1932)
R. C. Moore (1932)
Joseph E. Morero (1933)
John M. Nisbet (1932)
Ed. W. Owen (1933)
Leon J. Pepperberg (1933)
Sidney Powers (1932)
R. D. Reed (1933)
A. H. Richards (1933)
Gayle Scott (1932)
F. C. Sealey (1932)
S. C. Stathers (1933)
Willis Storm (1932)
H. J. Wasson (1933)
Theron Wasson (1933)
John F. Weinzierl (1933)
R. B. Whitehead (1932)

RESEARCH COMMITTEE

Alex. W. McCoy (1932), *chairman*, 919 East Grand Avenue, Ponca City, Oklahoma
Donald C. Barton (1933), *vice-chairman*, Petroleum Building, Houston, Texas

C. R. Fettke (1932)
A. I. Levorsen (1932)
Sidney Powers (1932)
R. D. Reed (1932)
L. C. Snider (1932)
W. C. Spooner (1932)
W. E. Wrather (1932)
W. T. Thom, Jr. (1933)
F. M. Van Tuyl (1933)
M. G. Cheney (1934)
K. C. Heald (1934)
F. H. Lahee (1934)
H. A. Ley (1934)
R. C. Moore (1934)
F. B. Plummer (1934)

CONSTITUTION AND BY-LAWS

Frank R. Clark, *chairman*, Box 2064, Tulsa, Oklahoma

F. H. Lahee
R. S. McFarland

REPRESENTATIVES ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

R. C. Moore (1933)
Sidney Powers (1934)

REPRESENTATIVES ON NATIONAL STRATIGRAPHIC NOMENCLATURE COMMITTEE

A. I. Levorsen, *chairman*, 1740 South St. Louis Avenue, Tulsa, Oklahoma

M. G. Cheney
C. J. Hares

REVOLVING PUBLICATION FUND

E. DeGolyer, *chairman*, 65 Broadway, New York, N. Y.

RESEARCH FUND

Luther H. White, *chairman*, J. A. Hull Oil Company, Tulsa, Oklahoma

Memorial

CORBIN DRUMMOND FLETCHER

C. D. Fletcher, active member of the Association, died at a hospital in Meridian, Mississippi, on April 5, 1931. His untimely death was caused by a peculiar accident. Fletcher and Henry N. Toler stopped to eat their lunch on the porch of an abandoned dwelling 10 miles from Riderwood, Alabama. The lunch had been consumed and they were nearly ready to leave to resume work when Toler heard the timbers holding the roof of the porch crack. Instinctively, he jumped from the porch and was not harmed. He returned to find that Fletcher had been struck by the falling timbers. Toler's efforts to revive him were unavailing and he drove about one-half mile for assistance. Fletcher was first taken to a small hospital at Riderwood, where the attending physician attempted to revive him. An examination showed that he was seriously injured, and it was necessary to take him to the hospital at Meridian, where facilities for more efficient medical treatment could be obtained.

Corbin Drummond Fletcher, son of Robert Poulson Fletcher and Mary Cox Fletcher, was born in Wilmington, Delaware, July 1, 1900. He was the grandson of Dr. Corbin Drummond Fletcher, a native of Accomac County, Virginia, who died in February, 1865, while serving as brigade surgeon (Wise's Brigade) in the Confederate Army.

Mr. Fletcher attended Friend's School and the City High School of Wilmington, Delaware. He attended Urbana University at Urbana, Ohio, from September 15, 1915, to June, 1916. He entered the freshman class at the University of Delaware in the fall of 1916 and left the University in the spring of 1917 without his parents' knowledge, in order to join the United States Army. He enlisted at Philadelphia, Pennsylvania, on April 28, 1917, and was assigned to Headquarters Company, Twenty-First Machine Gun Battalion. His company was assigned to service on the Mexican Border at Forts Bliss and Baker, Texas. From the border his company was sent over-seas, to France, in July, 1918, and almost immediately went into action at the front in the Meuse-Argonne sector, where he was severely gassed, resulting in tuberculosis and a nervous breakdown. He was treated in the field hospital and at Toul, France. He was sent to Roosevelt Hospital in New York, and thence to Camp Wadsworth Hospital near Spartanburg, South Carolina, where he was discharged from the Army on May 12, 1919.

After discharge from the Army, he was sent to a government hospital at Greenville, South Carolina. After being discharged from the hospital, he enrolled in the University of Oklahoma and afterward attended the School of Mines, University of Texas, at El Paso. He completed his education at Columbia University in New York where he majored in geology and received his B. S. degree in 1923.

In June, 1923, he married Miss Ebba Carell of Brooklyn, New York.

His first position was as instrument man for the Carter Oil Company in South Dakota, Wyoming, and Montana, from June, 1920, to October, 1920. From September, 1923, to June, 1924, half of his time was spent in research work on microscopic paleontology for J. J. Galloway of the International Petroleum Company of New York City. His next position was as paleontologist for the Atlantic Oil Producing Company of Dallas, Texas, from June, 1924, to October, 1924. After the termination of the work, he again did half-time paleontological research work in New York, this time for the Atlantic Oil Producing Company from October, 1924, until January, 1925. From January, 1925, until May, 1926, he was paleontologist for the Atlantic Oil Producing Company, first at Dallas, Texas, and later at Shreveport, Louisiana. Mr. Fletcher was paleontologist for the Gulf Refining Company of Louisiana from May, 1926, until February 1, 1931. The first three years of his work with the Gulf were spent in the office at Shreveport. The remaining time was spent in Mississippi and Alabama, where he had charge of core-drill operations. After leaving the Gulf, he established the firm of Fletcher and Toler, with headquarters at Jackson, Mississippi.

Representatives of the large oil companies and independent operators recognized his professional ability. His work on the Lower Cretaceous formations on the Sabine uplift has not been published, and this will be a loss to the profession.

The Association has lost a valuable personality. Sincerity and frankness were his most striking characteristics. He possessed thoughtfulness and consideration for others that were most evident in time of adversity. He was essentially serious-minded in regard to his work, and thoroughly loyal to his company.

Besides his wife, Ebba Carell Fletcher, who is now living with her parents in Brooklyn, the deceased is survived by a son, Corbin Drummond Fletcher, three and one-half years of age; a daughter, Ann Carell Fletcher, nine months old; his father and mother, Mr. and Mrs. Robert Poulson Fletcher of Easton, Maryland; two brothers, R. P. Fletcher, Jr., of Wilmington, Delaware, and Northrop Fletcher of Ecuador, South America; three married sisters, Mrs. Walter Dent Smith of Wilmington, Delaware, Mrs. Henry Burmann of Long Beach, California, and Mrs. Robert V. Williamson of Milwaukee, Wisconsin; and an uncle, Admiral Frank Schoffield of Washington, D. C.

SIDNEY E. MIX

SHREVEPORT, LOUISIANA
June 2, 1931

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

Employment

The Association maintains an employment service at headquarters under the supervision of the business manager.

This service is available to members and associates who desire new positions and to companies and others who desire Association members and associates as employees. All requests and information are handled confidentially and gratuitously.

To make this service of maximum value, all members and associates in the Association are requested to coöperate by notifying the business manager of openings available.

A 1,700-mile cross-section project, traversing the central United States, is being sponsored by the Kansas Geological Society in the interests of its Fifth Annual Field Conference to be held next September in Oklahoma and Arkansas. The section extends from Lake Superior through Michigan, Wisconsin, Iowa, northwestern Missouri, eastern Kansas, eastern Oklahoma, north-central and southwestern Texas to Rio Grande River. Constructed on sea-level datum, with a horizontal scale of 1 inch to 20 miles and a vertical scale of 1 inch to 400 feet, the final product will be approximately 3 × 7 feet in size. Correlations will be made largely by sample analysis of well cuttings, and the section will show in detail the principal subsurface stratigraphic units from the surface to the pre-Cambrian. The project is in charge of Anthony Folger. Those responsible for preparing the individual state sections are: Michigan and Wisconsin, Fred T. Thwaites; Iowa, James H. Lees; Missouri, H. S. McQueen; Kansas, Roy H. Hall; Oklahoma, Fred A. Bush; Texas, M. G. Cheney. Copies of this section will be included in the Guide Book of the field conference, which will contain many other maps and charts, as well as much unpublished descriptive material pertaining to the area covered by the conference. Copies of the Guide Book will be for sale by the Kansas Geological Society. Orders, or requests for information, should be addressed to the Field Conference Committee, 412 Union National Bank Building, Wichita, Kansas.

On May 25, a group of San Angelo geologists organized a luncheon club to be known as The San Angelo Conglomerates. B. H. Bentley, of the Republic Production Company, was elected "Big Boulder"; Nate Isenberger, consulting geologist, was elected "Cobblestone"; and E. L. Jones, of the Shell Petroleum Corporation, was elected "Gravel." It is the intention of The San Angelo Conglomerates to meet every other Monday noon at the St. Angelus Hotel for luncheon and discussion.

The West Texas Geological Society held its regular monthly meeting Saturday, May 30, on the roof of the St. Angelus Hotel, San Angelo, Texas. About forty geologists heard R. L. CANNON and JOE CANNON present a paper entitled "Structural Development of the South Permian Basin Area of West Texas with Particular Regard to its Effect on Stratigraphy."

The review *Scientia* has founded an Eugenio Rignano Prize, of the value of 10,000 Italian lire (approximately $525.00), to be conferred by international competition upon the author of the best essay on "The Evolution of the Notion of Time." The competition closes on December 31, 1932. For further information apply to the editor of *Scientia*, 12 Via A. De Togni, Milano (116), Italy.

Mr. and Mrs. A. R. DENISON announce the birth of Cordelia Ann Denison on May 28, at Fort Worth, Texas.

R. A. RANK, 2525 Fairfield Avenue, Shreveport, Louisiana, has returned to the United States after working as geologist during the past two years for the Creole Petroleum Corporation in Venezuela.

A. F. MELCHER, of the Petroleum Engineering Laboratories, Tulsa, Oklahoma, and Bradford, Pennsylvania, has closed the Bradford office for the present. Inquiries may be directed to the Tulsa office, 1137 North Cheyenne Avenue.

W. P. WOODRING, of the U. S. Geological Survey, is mapping the surface geology of Kettleman Hills, California.

H. D. MISER, of the U. S. Geological Survey, is spending part of the summer in Oklahoma and Arkansas.

PHILIP B. KING, of the U. S. Geological Survey, is mapping the eastern Marathon Mountains and the Diablo Plateau, Texas.

THOMAS A. HENDRICKS, of the U. S. Geological Survey, is continuing his surface mapping of the McAlester coal basin from McAlester, Oklahoma, to the Arkansas state line.

RALPH W. RICHARDS, of the U. S. Geological Survey, is working in Alaska.

GEORGE R. ELLIOTT was petroleum engineer for the Department of the Interior at Calgary since 1928. In February, 1931, he was appointed district petroleum and natural gas engineer for the Government of Alberta, with offices at Lethbridge. This is to correct an item in the May *Bulletin*.

HARLAN A. SPROWLS, formerly with F. E. Kistler and Company, is now vice-president and general manager of the Indiana Southwestern Gas Corporation at Vincennes, Indiana.

C. W. SANDERS, JR., has been transferred to Amarillo, Texas, as district geologist for the Shell Petroleum Corporation.

Mr. and Mrs. SHERWOOD BUCKSTAFF announce the arrival of a daughter, Joan Griswold, at Chickasha, Oklahoma, May 18, 1931. Mr. Buckstaff is geologist at Pauls Valley, Oklahoma, for the Shell Petroleum Corporation.

HENRY SCHWEER, Norman, Oklahoma, recently addressed the Oklahoma City Geological Society on "The Permian of Western Oklahoma." The division of this series was much the same as that presented by Mr. Schweer before the San Antonio convention of the Association.

ALFRED WEGENER, professor at the University of Graz, Austria, and leader of the German Scientific Expedition, died in Greenland.

GLENN R. V. GRIFFITH, formerly of the United Natural Gas Company, is now assistant petroleum engineer in the Tulsa office of the U. S. Geological Survey.

CHARLES WILLIAM HONESS and Lydia Savelle Ligon of Tulsa, Oklahoma, were married on June 6, 1931. Mr. Honess is in the geological department of the Gypsy Oil Company.

The Geological Society of New Mexico elected the following officers on May 15: president, J. B. HEADLEY, Southern Petroleum Exploration Company, Roswell; vice-president, E. A. OBERING, Shell Petroleum Corporation, Carlsbad; secretary, DELMAR R. GUINN, Empire Gas and Fuel Company, Roswell; and treasurer, T. F. PETTY, Humble Oil and Refining Company, Roswell, New Mexico.

Mr. and Mrs. J. LAUER STAUFT, of Negritos, Peru, are spending four months' leave in the United States and Canada.

JOSEPH STANLEY HOOK may be addressed at 4211 Berryman Avenue, Culver City, California.

CHARLES R. FETTKE, professor of geology, Carnegie Institute, is carrying on subsurface studies of the new gas field in Tioga County, Pennsylvania.

WILLIAM F. LOWE, in *International Petroleum Technology* for May, has an illustrated article, "Relation of Minor Folds to Earth Deformation," which is a review of a paper by L. L. FOLEY, geologist of the Mid-Kansas Oil and Gas Company, Tulsa, on "A New Theory of Earth Deformation and Application to the Mid-Continent Region," read before the Tulsa Geological Society, April 20.

RONALD K. DEFORD, division geologist with the Midwest Refining Company at Roswell, has been elected district representative of the newly established New Mexico district of the Association.

W. P. HASEMAN, consulting petroleum engineer, Oklahoma City, Oklahoma, has an article on "The Well Method of Producing Oil," in *The Petroleum Engineer* Midyear number.

A. W. DUSTON, consulting geologist, 415 Philtower Building, Tulsa, was recently elected president of the Mid-Continent Royalty Owners Association.

W. T. DOHERTY, STANLEY GILL, and C. P. PARSONS, have an article on "Drilling Fluid Problems on Gulf Coast," in the June 11 issue of *The Oil and Gas Journal.*

P. R. YEWELL, formerly San Angelo district geologist for Skelly Oil Company, has gone to Los Angeles for an indefinite period.

RICHARD E. KOCH is now working in the head office of the Dutch Shell Oil Company, The Hague, Holland.

RALPH C. BREHM, of the Producers and Refiners Corporation, Tulsa, and Miss Ruth Seekatz, Tulsa, were married on June 10.

JERRY E. UPP, recently micropaleontologist with The Pure Oil Company at Tulsa, Oklahoma, is assistant geologist with the Nebraska Geological Survey, Lincoln, Nebraska.

EDGAR D. CAHILL, formerly in the geological department of the Skelly Oil Company at Wichita, Kansas, may be addressed at 4475 Lindell Boulevard, St. Louis, Missouri.

DAVID DONOGHUE, consulting geologist, Fort Worth, Texas, and formerly with the Texas Pacific Coal and Oil Company, is returning to private practice after having spent a year as technical adviser of the Central Proration Committee of Texas.

A. W. AMBROSE has been appointed assistant general manager of the Empire Companies, Bartlesville, Oklahoma.

KINGSLEY CAMDEN MITCHELL, assistant geologist for the Richmond Petroleum Company, was killed, June 12, near Mier, Tamaulipas, Mexico.

IAN CAMPBELL has been an instructor in mineralogy and petrology at Harvard University during the past three years, two summers of which he spent in work on his doctor's thesis, "The Petrography of the Tonopah Mining District, Nevada," by assisting T. B. NOLAN in his re-survey of the Tonopah district for the United States Geological Survey. Dr. Campbell is now assistant professor of geology at the California Institute of Technology, Pasadena, California, handling the courses in petrology.

AMIL A. ANDERSON, of Anderson and Anderson, mining engineers and petroleum geologists, Wichita, Kansas, may be addressed at Box 189, Taft, California.

R. G. MAXWELL, formerly geologist with the Phillips Petroleum Company at Refugio, Texas, is employed by Merry Brothers and Perini, Paducah, Texas.

GEORGE E. BURTON, recently of Ardmore, Oklahoma, is at 204 West Third Street, Sheridan, Indiana.

JOSEPH H. SINCLAIR, of Brown Brothers and Company, 59 Wall Street, New York, has an illustrated article, "Treasure Hunting for Big Business," in *The Elks Magazine* for June.

HENRY B. MILNER, author of *Sedimentary Petrography*, and for some years lecturer in oil technology at the Imperial College of Science and Technology, London, has resigned his appointment there and is located as a consulting geologist and petroleum technologist at 92 Victoria Street, Westminster, London, S. W. 1.

JOHN L. RICH will teach economic geology at the University of Cincinnati next year.

WILLIAM J. KEMNITZER, co-author with RALPH ARNOLD of *Petroleum in the United States and Possessions*, a 1,100-page book to be released by Harper and Brothers, New York, this month, has accepted a position as director of research for the J. Edward Jones oil royalty organization in New York.

PHILIP S. SCHOENECK, formerly with the Atlantic Oil Producing Company, Big Spring, Texas, is now with the Atlantic Refining Company in Cuba. His address is Apartado 300, Caibarien, Cuba.

G. MARSHALL KAY, of Columbia University, New York City, has an article on "Stratigraphy of the Ordovician Hounsfield Metabentonite" in the May-June issue of *The Journal of Geology*.

BULLETIN ADVERTISERS

PROFESSIONAL CARDS

GEOLOGICAL SOCIETIES

Please use this REQUEST COUPON. Check items desired.

To The American Association of Petroleum Geologists Bulletin Advertiser

(Name and address)..

Please send me (check desired item):

☐ Information about........................ ☐ List of publications

☐ Your catalog ☐ Price of..................................

☐ Copy of.................................. ☐ ....

From The American Association of Petroleum Geologists Bulletin Reader

(Name)...

(Address).......................................